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

November 8, 2017

Site Vice President
Entergy Operations, Inc.
Waterford Steam Electric Station,
 Unit 3
17265 River Road
Killona, LA 70057-3093

SUBJECT: NUCLEAR REGULATORY COMMISSION REPORT FOR THE AUDIT OF ENTERGY NUCLEAR OPERATIONS, INC'S. FLOOD HAZARD REEVALUATION REPORT SUBMITTAL RELATING TO THE NEAR-TERM TASK FORCE RECOMMENDATION 2.1-FLOODING FOR WATERFORD STEAM ELECTRIC STATION, UNIT 3 (CAC NO. MF6086; EPID L-2015-JLD-0020)

Dear Sir or Madam:

By letter dated August 25, 2015 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML15231A354), the U.S. Nuclear Regulatory Commission (NRC) informed you of the staff's plan to conduct a regulatory audit of Entergy Nuclear Operations, Inc.'s (the licensee) Flood Hazard Reevaluation Report (FHRR) submittal related to the Near-Term Task Force Recommendation 2.1-Flooding for Waterford Steam Electric Station, Unit 3. The audit was intended to support the NRC staff review of the licensee's FHRR and the subsequent issuance of a staff assessment.

The audit conducted on March 3, 2016, was performed consistent with NRC Office of Nuclear Reactor Regulation, Office Instruction LIC-111, "Regulatory Audits," dated December 29, 2008, (ADAMS Accession No. ML082900195). The purpose of this letter is to provide you with the final audit report which summarizes and documents the NRC's regulatory audit of the licensee's FHRR submittal.

If you have any questions, please contact me at (301) 415-1132 or by e-mail at Joseph.Sebrosky@nrc.gov.

Sincerely,

Joseph Sebrosky, Senior Project Manager
Beyond-Design-Basis Management Branch
Division of Licensing Projects
Office of Nuclear Reactor Regulation

Docket No. 50-382

Enclosure:
Audit Report

cc w/encl: Distribution via Listserv

UNITED STATES
NUCLEAR REGULATORY COMMISSION
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NUCLEAR REGULATORY COMMISSION AUDIT REPORT

FOR THE AUDIT OF ENTERGY NUCLEAR OPERATIONS, INC'S.

FLOOD HAZARD REEVALUATION REPORT SUBMITTALS

RELATING TO THE NEAR-TERM TASK FORCE RECOMMENDATION 2.1-FLOODING FOR

WATERFORD STEAM ELECTRIC STATION, UNIT 3

BACKGROUND AND AUDIT BASIS

By letter dated March 12, 2012, 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. Recommendation 2.1 in that document recommended that the NRC staff issue orders to all licensees to reevaluate seismic and flooding hazards for their sites against current NRC requirements and guidance. Subsequent staff requirements memoranda associated with SECY 11-0124 and SECY-11-0137, instructed the NRC staff to issue requests for information to licensees pursuant to 10 CFR 50.54(f).

By letter dated July 21, 2015 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML15204A321), Entergy Nuclear Operations, Inc.'s (Entergy, the licensee) submitted its Flood Hazard Reevaluation Reports (FHRRs) for Waterford Steam Electric Station, Unit 3 (Waterford, WSES). The NRC has completed a regulatory audit of the licensee to better understand the development of the submittal, identify any similarities/differences with past work completed and ultimately aid in its review of the licensee's FHRR. This audit summary is being completed in accordance with the guidance set forth in NRC Office of Nuclear Reactor Regulation, Office Instruction LIC-111, "Regulatory Audits," dated December 29, 2008 (ADAMS Accession No. ML082900195).

AUDIT LOCATION AND DATES

The audit was completed by document review via a webinar session in conjunction with the use of the licensee's established electronic reading room (ERR) and webinar on March 3, 2016.

Enclosure

AUDIT TEAM

The NRC audit team, and audit partipants were as follows:

NRC AUDIT TEAM	Organization
Victor Hall, Team Leader	NRR
Lyle Hibler, Technical Lead	NRO
Andy Campbell	NRO
Chris Cook	NRO
Hosung Ahn	NRO
Frances Ramirez	RIV
Stewart Bailey	NRR
Jessie Quichocho	NRR
Matthew McConnell	NRR
Joshua Miller	NRR
Kevin Roche	NRR
Scott DeNeale	Oak Ridge National Laboratory (ORNL)
David Watson	ORNL
Sudershan Gangrade	ORNL
Chris Bender	Taylor Engineering

AUDIT PARTICIPANTS	Organization
Don Bentley	Entergy
Mike Krupa	Entergy
Alan Harris	Entergy
Stephen Picard	Entergy
Dan Brown	AREVA
Cindy Fasano	AREVA
Chad Cox	GZA
David Leone	GZA
Brian Furtado	GZA

DOCUMENTS AUDITED

Attachment 1 of this report contains a list which details the documents that were reviewed by the NRC staff, in part or in whole, as part of this audit. The documents were located in an ERR during the NRC staff's review. Attachment 2 provides a discussion of the information needs and response to those needs that were addressed as part of the audit. Attachment 3 provides a table of a levee failure analysis.

AUDIT ACTIVITIES

In general, the audit activities consisted mainly of the following actions:

- Review background information on site topography and geographical characteristics of the watershed.
- Review site physical features and plant layout.
- Understand the selection of important assumptions and parameters that would be the basis for evaluating the individual flood causing mechanisms described in the 50.54(f) letter.
- Review model input/output files to computer analyses such as Hydrologic Engineering Center - Hydrologic Modeling System (HEC-HMS) and FLO-2D to have an understanding of how modeling assumptions were programmed and executed.

Attachment 2 summarizes specific technical topics (and resolution) of important items that were discussed and clarified during the audit. The items discussed in Attachment 2 may be referenced/mentioned in the staff assessment in more detail.

EXIT MEETING/BRIEFING

By letter dated April 12, 2016 (ADAMS Accession No. ML16090A327), the NRC staff issued a summary of the reevaluated flood-causing mechanisms. That letter concluded that the licensee's reevaluated flooding hazard information is a suitable input for assessments associated with Near-Term Task Force Recommendation 2.1 "Flooding." A closeout phone call was held with the licensee on November xx, 2017. The NRC communicated that no findings or oen/unresolved issues remain.

Attachments:
1) Waterford Steam Electric Station, Unit 3 Audit Document List
2) Waterford Steam Electric Station, Unit 3 Information Needs and Responses
3) Waterford Steam Electric Station, Unit 3 Tables and Figures

ATTACHMENT 1

Waterford Steam Electric Station, Unit 3 Audit Document List

1. AREVA, 2014a, "Waterford Steam Electric Station Flooding Hazard Re-evaluation – Nuclear Power Island Structure Local Intense Precipitation," Rev 000, AREVA Document No. 32-9221496-000 (Entergy Nuclear WF3-CS-15-00018 Rev 0, EC No. 59098, Vendor Document No. 32-9231496-000), 2014, Signed August 13, 2015. Posted to Curtiss-Wright ERR as "Local Intense Precipitation Internal to the NPIS" on September 14, 2015.

2. AREVA, 2014b, "Waterford Steam Electric Station Flooding Hazard Re-evaluation – Ice Induced Flooding," Rev 000, AREVA Document No. 32-9227011-000 (Entergy Nuclear WF3-CS-15-00016 Rev 0, EC No. 59098, Vendor Document No. 32-9227011-000), Signed September 25, 2014. Posted to Curtiss-Wright ERR as "Ice Induced Flooding" on September 14, 2015.

3. AREVA, 2014c, "Waterford Steam Electric Station Flooding Hazard Re-evaluation – Channel Diversion," Rev 000, AREVA Document No. 51-9227014-000 (Entergy Nuclear WF3-CS-15-00032 Rev 0, EC No. 59098), Signed September 26, 2014. Posted to Curtiss-Wright ERR as "Channel Diversion" on September 14, 2015.

4. AREVA, 2014d, "Waterford Steam Electric Station Flooding Hazard Re-evaluation – Local Intense Precipitation," Rev 000, AREVA Document No. 32-9226993-000 (Entergy Nuclear WF3-CS-15-00011 Rev 0, EC No. 59098, Vendor Document No. 32-9226993-000), Signed December 16, 2014. Posted to Curtiss-Wright ERR as "LIP External to Nuclear Plant Island Structure" on September 14, 2015.

5. Entergy, 2014e. WSES Procedure Number OP-901-521 (Attachment 4) – "Severe Weather and Flooding," Revision 315, 2015. See AREVA Document No. 38-9243507-000.

6. AREVA, 2015a, "Waterford Steam Electric Station Flooding Hazard Re-evaluation – Dam Failure," Rev 000, AREVA Document No. 32-9226999-000 (Entergy Nuclear WF3-CS-15-00013 Rev 0, EC No. 59098), Vendor Document No. 32-9226999-000), 2015, Signed January 22, 2015. Posted to Curtiss-Wright ERR as "Dam Failure" on September 14, 2015.

7. AREVA, 2015b, "Waterford Steam Electric Station Flooding Hazard Re-evaluation – Probable Maximum Precipitation," Rev 000, AREVA Document No. 32-9233937-000 (Entergy Nuclear WF3-CS-15-00019 Rev 0, EC No. 59098, Vendor Document No. 32-9233937-000), 2015, Signed March 23, 2015. Posted to Curtiss-Wright ERR as "Probable Maximum Precipitation" on September 14, 2015.

8. AREVA, 2015c, "Waterford Steam Electric Station Flooding Hazard Re-evaluation – Nuclear Power Island Structure Local Intense Precipitation," Rev 000, AREVA Document No. 32-9231496-000, Entergy Nuclear signed May 1, 2015. Included on hard drive submitted to NRC on September 4, 2015.

9. AREVA, 2015d, "Waterford Steam Electric Station Flooding Hazard Re-evaluation – Combined Effects," Rev 000, AREVA Document No. 51-9227036-000 (Entergy Nuclear WF3-CS-15-00017 Rev 0, EC No. 59098, Vendor Document No. 32-9227036-000), Signed June 8, 2015. Posted to Curtiss-Wright ERR as "Combined Effects" on September 14, 2015.

10. AREVA, 2015e, "Waterford Steam Electric Station Flooding Hazard Re-Evaluation Report," Rev 000, AREVA Document No. 51-9227040-000 (Entergy Nuclear WF3-CS-15-00010 Rev 0, EC No. 58788, Vendor Document No. 51-9227040-00), 2015, Signed July 9, 2015. Posted to Curtiss-Wright ERR as "Flood Hazard Reevaluation Report" on September 14, 2015.

11. AREVA, 2015f, "Waterford Steam Electric Station Flooding Hazard Re-evaluation – Probable Maximum Flood," Rev 000, AREVA Document No. 32-9226996-000 (Entergy Nuclear WF3-CS-15-00012 Rev 0, EC No. 59098, Vendor Document No. 32-9226996-000), Signed August 13, 2015. Posted to Curtiss-Wright ERR as "Probable Maximum Flood" on September 14, 2015.

12. AREVA, 2015g, "Waterford Steam Electric Station Flooding Hazard Re-evaluation – Probable Maximum Hurricane," Rev 000, AREVA Document No. 32-9227002-000 (Entergy Nuclear WF3-CS-15-00014 Rev 0, EC No. 59098, Vendor Document No. 32-9227002-000), Signed August 13, 2015. Posted to Curtiss-Wright ERR as "Probable Maximum Hurricane" on September 14, 2015.

13. AREVA, 2015h, "Waterford Steam Electric Station Flooding Hazard Re-evaluation – Probable Maximum Storm Surge," Rev 000, AREVA Document No. 32-9227005-000 (Entergy Nuclear WF3-CS-15-00015 Rev 0, EC No. 59098, Vendor Document No. 32-9227005-000)," Signed August 13, 2015. Posted to Curtiss-Wright ERR as "Probable Maximum Storm Surge" on September 14, 2015.

14. AREVA, 2015i, "Waterford Steam Electric Station Unit 3 Fukushima Flood Hazard Re-evaluation – Topographic Survey," Rev 000, AREVA Document No. 38-9226991-000 (Entergy Nuclear WF3-CS-15-00022 Rev 0, EC No. 59098, Vendor Document No. 32-9226991-000), Signed August 13, 2015. Posted to Curtiss-Wright ERR as "Topographic Survey" on September 14, 2015.

15. AREVA, 2015j, "Waterford Steam Electric Station Flooding Hazard Re-evaluation – Tsunami," Rev 000, AREVA Document No. 51-9227008-000 (Entergy Nuclear WF3-CS-15-00020 Rev 0, EC No. 59098, Vendor Document No. 51-9227008-000), Entergy Nuclear signed August 13, 2015. Posted to Curtiss-Wright ERR as "Tsunami" on September 14, 2015.

16. Entergy Operations, Inc. (Entergy), 1992, Waterford Steam Electric Station Drawing No. G-886, "Reactor Building Plan El. 21.00 Plumbing & Drainage", February 6, 1992.

17. Entergy, 2000, "Route DCT Sumps Discharge to Circulating Water System," DC3521 Revision 4, Signed January 26, 2000. Letter dated February 3, 2000.

18. Entergy, 2001, AREVA Document No. 38-9243507-000, Calculation EC-M99-010 Revision 0-2, Signed August 24, 2001.

19. Entergy, 2002, "Route DCT Sumps Discharge to Circulating Water System," DC 3521 Revision 6, Signed May 7, 2002.

20. Entergy, 2013, Final Safety Analysis Report-Revision 307, Letter dated July 11, 2013, ADAMS Accession No. ML13218A409 (Non-Public).

21. Entergy, 2015a, "Waterford Steam Electric Station Flooding Hazard Re-evaluation Report," Enclosure to Letter from Michael R. Chisum to the NRC Document Control

Desk, Subject: “Flood Hazard Reevaluation Report Waterford Steam Electric Station, Unit 3 (Waterford 3)", July 21, 2015, ADAMS Accession No. ML15204A344.

22. Entergy, 2015b, “Flood Hazard Re-evaluation for Waterford Steam Electric Station,” Letter from Cynthia Fasano, Advisory Engineer, AREVA Inc. to Victor Hall, Project Manager, U.S. Nuclear Regulatory Commission, Enclosure hard drives of files, September 4, 2015, ADAMS Accession No. ML17208A033.

23. Entergy, 2015c, "(Off Normal Procedure) Severe Weather and Flooding," OP-901-521, Effective Date: 7/2/2015, Signed: 7/20/2015

24. Entergy, 2016a, “Waterford Steam Electric Station Flood Re-evaluation Audit – March, 2016”. Posted to Curtiss-Wright ERR as “WSES Audit Slides 3-3-16” on March 3, 2016.

25. Entergy, 2016b, “Waterford Steam Electric Station (WSES) Information Need Responses for the Flood Hazard Reevaluation Report,” enclosures Attachment A (for Information Need 1), Attachment B (for Information Need 3), Attachment C (for Information Need 6), Attachment D (for Information Need 7), Attachment E (for Information Needs 10 and 13), Attachment F (for Information Need 12). Posted to Curtiss-Wright electronic reading room (ERR) on January 31, 2016.

ATTACHMENT 2

Waterford Steam Electric Station, Unit 3 Information Needs and Responses

Information Need No.	Information Need Description	Response
1	<u>**Figures**</u> <u>Background</u>: Figures from the Combined Effects Calculation Package (AREVA, 2015b)) will need to be included in the U.S Nuclear Regulatory Commission (NRC) staff assessment. <u>Request</u>: Provide legible, standalone copies of the following figures from the Combined Effects Calculation Package (AREVA, 2015b): • Figure 5 (*FLO-2D Model Layout*) • Figure 6 (*FLO-2D Manning's Roughness Coefficient Rendering*) • Figure 11 (Selected Locations at Waterford Steam Electric Station [WSES] for Reporting Results) • Figure 40 (Water Level Timeseries Plot for Storm 302 in WSES Plant Datum [feet, Mean Sea Level (MSL)]) • Figure 41 (*Water Level Timeseries Plot for Storm 402c in WSES Plant Datum [feet, MSL]*)	Attachment A of the response (Entergy, 2016a) provided the requested figures. The NRC staff reviewed the response and concluded the information provided was sufficient to resolve the information need. The staff and the licensee agreed the staff could use the following figures from the response in the staff assessment: 1. Figure 6: FLO-2D Manning's Roughness Rendering 2. Figure 11: Selected Locations at WSES for Reporting Results
2	<u>**All Flood-Causing Mechanisms – Comparison of Reevaluated Flood Hazard with Current Design Basis**</u> <u>Background</u>: Recommendation 2.1 of the 50.54(f) letter (NRC, 2012) provides instructions for the Flood Hazard Reevaluation Report (FHRR). Under Section 1, Hazard Reevaluation Report, Items c and d, licensees are requested to perform:	The response (Entergy, 2016a) stated that "[f]or the purposes of the WSES FHRR, the two terms, design basis and licensing basis, can be considered to have the same meaning and may be used interchangeably." The licensee stated in the response that "flood levels reported within the Mississippi River refer to flooding that remains within the bounds of the Mississippi River levee network. Flood levels reported as being at the WSES site refer to flooding within the

Information Need No.	Information Need Description	Response
	c. Comparison of current and reevaluated flood-causing mechanisms at the site. Provide an assessment of the current design basis (CDB) flood elevation to the reevaluated flood elevation for each flood causing mechanism. Include how the findings from Enclosure 4 of this letter (i.e., Recommendation 2.3 flooding walkdowns) support this determination. If the CDB flood bounds the reevaluated hazard for all flood-causing mechanisms, include how this finding was determined. d. Interim evaluation and actions taken or planned to address any higher flooding hazards relative to the design-basis, prior to completion of the integrated assessment described below, if necessary. The FHRR for the WSES site mentions both the design-basis and licensing basis when comparing to reevaluated flood hazards and it is not clear which is correct due to inconsistencies. For example, in Section 4.0 the text tends to refer to the licensing basis, but for the flood elevation comparison presented on Table 4-1 the same values are referred to as the design-basis. It is particularly unclear if the 1.6 feet (ft.) Dry Cooling Tower ponding level is a design or licensing basis since the reference for this level is WSES Calculation EC-M99-010, Revision 0-2, August 2001(Entergy, 2001a) not the revised WSES Updated Final Safety Analysis Report (UFSAR) (Entergy, 2013). There is also some ambiguity in the wording of the FHRR which causes confusion with whether the design basis or licensing basis levels are for the Mississippi	flood plain (no longer bound by the levee network) that could inundate the site. Where not specified (i.e. FHRR Table 4-1 probable maximum storm surge [PMSS] from Gulf of Mexico), the flood elevation refers to the WSES site. The CDB includes flood levels both within the Mississippi River levee network, as well as flood levels outside of the levee network which could potentially inundate the area around the site structures (i.e., inundation of the flood plain outside of the levee network)". The licensee stated that "[t]he LIP Dry Cooling Tower (DCT) flood values reported in Table 4-1 are provided in terms of depth, not elevation. This is due to the varying relevant elevations of the two DCT basins. The elevation important to safety for the DCTs is the height (above the floor) of the lowest electrical termination in the Motor Control Center (MCC) in either of the DCT basins. Additionally, pooling water will impact the sump pump motors prior to reaching the level of the MCCs. The specific elevations are described below (from EC-M99-010). These elevations are based on a survey and may vary relative to design drawings". The response provides DCT A elevations (relative to MSL) for the floor, the sump pump motor, the MCC critical, and the reevaluated flood, and DCT B elevations (relative to MSL) for the floor, the sump pump motor, the MCC critical, and the reevaluated flood. The licensee stated in its response that "[f]or the purpose of impacting site safety, the MCC height and elevation for DCT B is considered the controlling parameter" and "[t]he design-basis for the internal LIP is described in UFSAR Section 2.4, pages 2.4-9 and 2.4-10. EC-M99-010 provides the technical basis for the UFSAR discussion regarding internal LIP flooding." The NRC staff determined that ponding depths rather than water surface elevations (WSE) were acceptable for

Information Need No.	Information Need Description	Response
	River or are established at the WSES site which is in the floodplain. In addition, the local intense precipitation (LIP) internal to the Nuclear Plant Island Structure (NPIS) values presented in the FHRR are reported as ponding depths and not elevations and therefore, the FHRR does not currently provide flooding elevations for the LIP internal to the NPIS analysis in Section 3.1 or in the Flood Elevation Comparison table, Table 4-1. <u>Request</u>: Clarify the inconsistencies identified in the FHRR with regard to the comparison of the reevaluated flood hazard to the CDB and submit a revised hazard comparison consistent with the instructions provided in the §50.54(f) letter. Also clarify whether the LIP values are ponding depths or elevations. If the values are ponding depths, provide the flood elevations.	characterization of the reevaluated LIP hazard within the NPIS. The NRC staff reviewed the response and concluded that the information provided by the licensee was sufficient to address the information need request. The staff and the licensee agreed the staff could use the following figure from the response in the staff assessment: 1. Figure 3-1 Motor-Driven Pump Locations
3	**<u>General – Nuclear Plant Island Structure</u>** <u>Background</u>: Section 2.2 of the FHRR (Entergy, 2015a) describes the NPIS as a rectangular, box-like reinforced concrete structure, surrounded by a wall with a minimum protection elevation of 29.25 ft. Mean Sea Level (MSL). The FHRR notes that all structures, systems and components (SSCs) important to safety are flood protected by the NPIS enclosure. <u>Request</u>: Describe the locations and elevations of the pumps within the NPIS, the conveyances through which the water is pumped, and the pump discharge points. Provide a detailed diagram	The response (Entergy, 2016a) refers to Figure 3-1 as provided in Attachment B, which is an update of FHRR Figure 3-4. The staff noted the updated figure includes the locations of multiple motor-driven pumps. The licensee also included the following clarifying response: "The motor driven pumps discharge to the circulating water system and the storm drainage network (see Figure 3-7; modified from plant drawing G173). The diesel drive pumps discharge over the NPIS wall, at elevation 30 ft MSL (see Figure 3-7, "Dry Cooling Tower Pump Routing" in Attachment B [to Entergy, 2016a])."

Information Need No.	Information Need Description	Response
	illustrating this information as a part of the response.	The response references AREVA, 2015a; Entergy, 2001b; Entergy, 1992a; Entergy 1992b; Entergy1998; and Entergy 2012[1]. The NRC staff reviewed the response and concluded that the information provided by the licensee was sufficient to address the information need request.
4	**<u>LIP – Precipitation</u>** <u>Background</u>: Evaluation of LIP flooding effects in the FHRR focused on two separate analyses: 1) a two-dimensional hydrodynamic simulation of flooding outside of the NPIS using FLO-2D PRO and 2) a mass-balance approach to simulate flooding within the NPIS (see WSES FHRR, AREVA Document No. 32-9231496-000, and AREVA Document No. 32-9226993-000) (Entergy, 2015a; AREVA, 2015a; AREVA, 2014). Although a site-specific probable maximum precipitation (ssPMP) study was conducted for LIP, it appears that the rainfall hyetograph resulting from this study was used for the mass-balance approach for simulating flooding within the NPIS, but higher Hydrometeorological Report (HMR) values are used for the two-dimensional model for simulating flooding outside the NPIS. <u>Request</u>: Discuss the rationale for using different rainfall inputs for the two LIP evaluations and how this impacts the predicted flooding levels inside the NPIS and outside the NPIS.	The licensee stated (Entergy, 2016a) that Hierarchical Hazard Assessment (HHA) was used for the LIP analysis but that the HHA approach for the LIP analysis outside the NPIS and inside the NPIS differed. As the first condition, the licensee considered that LIP flooding on the exterior of the NPIS could challenge the protection of the areas within the NPIS via ingress from areas external toward areas internal to the NPIS. As a second condition, the licensee considered that LIP directly over the interior of the NPIS could challenge the SCCs within the NPIS. The licensee applied the HHA approach to both of these conditions separately and this found that the HHA process terminated at different phases for both of these LIP flooding conditions. These two conditions are distinguished by use of the HMR probable maximum precipitation (PMP) for the exterior NPIS and the ssPMP for the interior NPIS. <u>Outside of the NPIS</u>: The licensee stated that no SSCs are located outside of the NPIS. HMR-based PMP values (more conservative than ssPMP values) were used for the external NPIS analysis. The available physical margin was not exceeded using the HHA process, so refinement (primarily addition of realism) of the review was stopped for the LIP analysis external to the NPIS. An analysis based on an ssPMP would only increase the margin. The licensee stated in its response that the (vertical) available

[1] Figures from these sources were provided by the licensee as Attachment B to Entergy (2016a).

Information Need No.	Information Need Description	Response
		physical margin between the ground surface just outside the NPIS and the 29.25 ft. MSL protection level ranges from 11.6 to 14.9 ft. Inside the NPIS: All WSES SSCs are internal to the NPIS, which is protected from external flooding to elevation 29.25 ft. MSL with watertight doors at elevations lower than that elevation. The available physical margin is smaller inside the NPIS (about 1.6 ft. of flooding depth) than outside of the NPIS and therefore, a more realistic rainfall analysis approach (i.e., an ssPMP) was used. The licensee stated that ssPMP was more realistic due to the historical storms considered in the analysis, including the use of more recent events than considered in the HMR analysis. The response references AREVA, 2014; NRC, 2011; Entergy, 2001; Entergy, 2013). The NRC staff reviewed the response and determined the information provided by the licensee was sufficient to address the information need request
5	**LIP – Roof Drainage and Sump Pump Discharges** Background: Section 3.1.2.3 of the FHRR (Entergy, 2015a) (also see AREVA Document No. 32-9231496-000 [AREVA, 2015a]) documents the calculation of water storage and conveyance for buildings, which considers the geometry of parapet walls, scuppers, and roof drains at various locations. Section 3.1.2.1 of the FHRR states that such conveyances "discharge outside of the NPIS" but does not describe how or where the flow is discharged. In contrast, the FLO-2D files provided lack any refined modeling to consider these features and instead models buildings as flat	The licensee references the response to Information Need No. 3 for sump pump and discharge locations (Entergy, 2016). Both sump pumps and roof drains are connected to the storm drain network which discharges at locations on north and east sides of the NPIS. The roof drains connect to the storm drain at locations along the perimeter of the NPIS. The licensee references figures which show the locations of storm drain network outfalls. The outfalls are located away from the perimeter of the NPIS and at ground elevations lower than that at the perimeter of the NPIS. The licensee stated that even if all of the rainfall into the NPIS area were discharged to a single location adjacent to the NPIS, the resulting water elevation

Information Need No.	Information Need Description	Response
	elevated grid elements of various heights. Rainfall simulated in FLO-2D as occurring on building rooftops appears to be routed to the lowest nearby grid element. Similarly it is not clear where water from sump pumps in the NPIS is routed to. Request: Clarify how rainfall onto building roofs and water from sump pumps in the NPIS are physically routed in the FLO-2D model, and demonstrate that the model implementation accounts for roof runoff and sump pump discharges in a manner consistent with physical reality. If, in reality, rainfall and sump pump discharges are routed to concentrated discharge points, provide a discussion of how the model simulates localized flooding impacts due to concentrated discharge. As necessary, provide sensitivity analysis results that demonstrate the significance of localized flooding impacts from roof and sump pump discharges associated with various operational assumptions.	would not exceed the physical margin available (11.6 to 14.9 ft. as described in Information Need No. 4 response). The licensee's response also clarified and justified the approach used for the routing of building roof drainage and sump pump water discharge in the FLO-2D model to the areas exterior to the NPIS. The licensee stated that drainage from localized points associated with parapet walls, scuppers and roof drains were not specifically modelled. The licensee configured the FLO-2D model to discharge all runoff from the NPIS at the lowest single grid point near the NPIS and the approach does not credit the areas within the NPIS that would store runoff within the NPIS. The licensee stated the FLO-2D analysis used the larger HMR-based PMP relative to the ssPMP for the analysis of LIP flooding of the exterior NPIS areas. The NRC staff reviewed the response and concluded that the information provided by the licensee was sufficient to address the information need request.
6	**LIP - Site Pumps Operation** Background: The FHRR states (Entergy, 2015a) that permanent and portable pumps will be operating after the onset of the LIP event as described in FHRR Section 2.2.1 as being vulnerable from the LIP event. The details of the justification for assuming pumping capacity and pump initiation time is not clear in the FHRR for the CDB and the reevaluated hazard. Reasonable justification should be based on pump classification consistent with Nuclear Energy Institute 12-07 (NEI, 2012), and Regulatory Guide 1.102 (NRC, 1976). Request: Provide the safety class (Category 1 safety related or important to safety) of existing	The licensee response (Entergy, 2016a) reference the "Equipment Database" and notes the following refers to both DCT basins: 1. SPMPMP0008A & B – Quality Rated "Important to Safety, Seismic II/I" 2. SPMPMP0014A & B – Quality Rated "Important to Safety, Seismic II/I" 3. SPMPMP0052A & B (Diesels) – Quality Rated "Important to Safety", Non-Seismic" "OP-901-521 Rev 316, which implemented the changes for the FHRR, is provided in Attachment C [in the ERR]. There is a

Information Need No.	Information Need Description	Response
	DCT A and DCT B pumps (referred to in FHRR Section 2.2.1) for the ultimate heatsink that are potentially vulnerable to the LIP event, used in the CDB and reevaluated hazard analysis. Provide how flood protection barriers (i.e. pumps) are classified (incorporated, exterior or temporary) for all credited pumps used in the LIP CDB and the reevaluated hazard analyses. If this information is not in the OP-901-521 (Entergy, 2014) Severe Weather and Flooding" Off-Normal Procedure, provide in the ERR the operating procedure documentation used for the CDB. Also provide in the ERR a copy of the revision to OP-901-521 described in the FHRR.	50.59 evaluation and other discussions about classification in the package." "Design Change Package 3521 Rev. 4, which implemented the mod[ification] to the procedure] to route the DCT Sumps to various locations and installed the Diesel sump pumps, is provided in Attachment C [in the ERR]." "Design Change Package 3521 Rev. 6, which is the final Rev of the package, is provided in Attachment C [in the ERR]." The response references Entergy, 2000; 2007; 2015b. The NRC staff reviewed the response and concluded that the information provided by the licensee was sufficient to address the information need request. The NRC staff notes that subsequent to the submittal of the FHRR, the licensee has also submitted the "Mitigation Strategies Assessment for Flooding Report" (Entergy, 2016b) and a Focused Evaluation for External Flooding for Waterford Steam Electric Station, Unit 3" (Entergy, 2017). Both of these reports discussed pump operations within the NPIS during LIP events.
7	**<u>LIP – Sump Pump Operation Assumptions</u>** <u>Background</u>: Section 3.1.2.3.3 of the FHRR (Entergy, 2015) (also see AREVA Document No. 32-9231496-000 [AREVA, 201x]) summarizes the pumping discharge assumptions used to evaluate LIP (NPIS-Internal) flooding in the Dry Cooling Tower (DCT) Basins. Per the FHRR, each DCT basin is hydraulically connected to one sump pump, each rated for 350 gallons per minute (gpm), but conservatively reduced to 300 gpm for this evaluation. In addition, it is assumed that the site	The licensee refers to response to Information Need No. 3 and its associated diagram showing the location of the sump pumps (Entergy, 2016a). The licensee states that "the design basis flood is established for a PMP event draining into the DCT basins. That design basis flood is calculated to be less than 1.6 ft of total flooding (flood depth). See also response to Information Need No. 2." In order to justify the basis for a 30-min standby time for Motor Driven Pumps, the licensee refers to Section 5.10 of EC-M99-

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	will face loss of off-site power (LOOP). In order to allow operators time to restart the pumps, the licensee assumes that these sump pumps do not begin operating until 30 minutes (min) after the start of precipitation. As a result, the licensee performed eight pump operational scenarios to calculate ponding depths in the DCT Basins. The most conservative scenario (Base Case) considered includes – "One installed sump pump for each DCT basin starting 30-min after the onset of precipitation (300 gpm)". In deciding on a stand-by time of 30-min, the licensee references Entergy (2001). From staff's review of AREVA Document No. 32-9231496-000, Appendix F, Attachment 8.1, (AREVA, 2015a) the design basis requirement for the DCT sump pumps *should consider*: To allow time for connecting the pumps to the functioning EDG [emergency diesel generators], a minimum of 30-min would elapse between commencement of the PMP and pump start. (A recommended evaluation would determine the maximum allowable elapsed time between commencement of PMP and pump start in order to establish a time margin for operator action). In addition, Section 2.3 of the FHRR describes that: During the design basis PMP event, it is assumed that one motor driven sump pump is engaged within 30 min of the onset of the event, and the diesel powered sump pump	010 (Entergy, 2001), which states that "Dry Cooling Tower sump pumps are not available for first 30-min of the PMP in order for operator actions to power the DCT pumps from the diesel-backed busses. This is based on Commitment P4392, which references CR-WF3-2007-1648 and evaluated the 30-min time requirement. CR-WF3-2007-1648 resulted in an Apparent Cause Evaluation and revisions to emergency operating procedures to ensure the remaining sump pump in each cooling tower is operating after the first half hour of the PMP with simultaneous LOOP (current revisions of relevant emergency operating procedures are provided in Attachment D in the ERR and are listed below): a) OP-902-003 b) OP-902-008 c) OP-902-009 Appendix 20 d) OP-500-002 CR Cabinet Window" Justification for using an ssPMP was provided in response to Information Need No. 4. Please refer to that table entry for details. The NRC staff reviewed the response and concluded that the information provided by the licensee was sufficient to address the information need request. The NRC staff notes that after the audit, the licensee submitted the "Mitigation Strategies Assessment for Flooding Report" (Entergy, 2016b) and a Focused Evaluation for External Flooding for Waterford Steam Electric Station, Unit 3" (Entergy, 2017), which further revised operating procedures for the LIP hazard. The NRC staff has completed the MSA review and determine the licensee's submittal was reasonable (NRC, 2017) and the focused evaluation is currently under staff review.

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	is engaged within 3 hours of the onset of the event. Additionally, Section 5.1.1 of the FHRR mentions that: The current design basis at WSES credits one motor driven sump pump activating 30 -min after the onset of the PMP event, and a diesel powered sump pump activating 3 hours after the onset of the PMP event. Based on the information provided in the FHRR and calculation packages, it is not clear whether the design-basis mitigating measures have been established for a LIP-type flood hazard and where the sump pumps discussed are located. Finally, based on the information provided in Section 5.1.2 of the FHRR, the licensee plans to adopt mitigating measures to ensure that two sump pumps are activated within 30-min after the onset of a LIP event. While the results of the LIP (NPIS-Internal) evaluation demonstrate that such an arrangement would avoid submerging the sump pumps under a site-specific PMP, staff sensitivity analysis indicates that the proposed solution would not prevent sump pump submergence under an HMR-based PMP. Request: Provide the following information: a) Discuss the locations, number, and availability of sump pumps servicing the DCT Basins, and provide a diagram which clearly shows the locations of all sump pumps included in the LIP (NPIS-	

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	Internal) evaluation and the locations of sump pump discharges. b) Clarify whether the design basis described in Section 2.3 of the FHRR is established for LIP (NPIS-Internal). c) Justify the use of 30-min as the stand-by time period between commencement of the PMP and start of pump operation. d) Provide justification for using a site-specific PMP rather than an HMR-based PMP for the LIP (NPIS-Internal) evaluation (see Information Need No. 4).	
8	**<u>Reevaluated and CDB Flood Heights</u>** <u>Background</u>: Table 4-1 in the FHRR (Entergy, 2015) reports the design-basis flood height and reevaluated flood height for various flood hazard mechanisms. The design-basis flood height for probable maximum flood (PMF) on the Mississippi River is reported as 27.0 ft. MSL in the Mississippi River, while the design-basis flood height for Combined Effect Flood is reported as 27.6 ft. MSL at WSES. Furthermore, the reevaluated flood height is reported as 29.9 ft. MSL in the Mississippi River for PMF, 29.9 ft. MSL in the Mississippi River for PMF + Dam Failure, and 20.6 ft. at WSES for PMF + Dam Failure. <u>Request</u>: Explain why an in-river reevaluated flood height is reported for PMF + Dam Failure flooding and for PMF flooding, while a reevaluated flood height at WSES is reported for PMF + Dam Failure flooding, but not for PMF flooding. Describe the significance of both design basis and reevaluated	The licensee stated in the response (Entergy, 2016a) that "the reevaluated PMF flood height at the WSES site (as opposed to within the river channel on the water side of the levee adjacent to the WSES site) is 20.0 ft. MSL," and "the reevaluated PMF flood height at WSES is bounded by the reevaluated PMF with Dam Failure flood height of 20.6 ft. MSL." The licensee stated in the responses that "the water surface elevation reported at WSES is the flood level directly applicable to the site. Flood levels in the Mississippi River were reported for the following reasons: a) for the PMF on the Mississippi River, only water levels in the Mississippi River were reported in the WSES Updated Final Safety Analysis Report (UFSAR)" Part 1) PMF flood level at WSES • The response provided a reevaluated flood height at WSES for PMF flooding – the stillwater value is 20.0 ft. MSL. This is bounded by PMF + upstream dam failure flooding at WSES (stillwater of 20.6 ft. MSL). • Section 5 of the FHRR states "Flooding due to Local Intense Precipitation and the CCEF are the only flood

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	flood heights being reported in the Mississippi River and how these elevations impact the WSES.	mechanisms which challenge the design basis of the WSES site." There is no CDB for flooding at WSES for PMF or PMF + Dam Failure. Part 2) Significance of flood levels being reported in the Mississippi River, • UFSAR only reports water levels in Mississippi River. For the FHRR, the Mississippi River values were reported for comparison to the UFSAR. • Used for assessment of levee failure potential • WSES existing procedure for calculating warning time is based on water levels in the Mississippi River. The response references Entergy, 2013; AREVA 2015c; and AREVA, 2015x. The NRC staff concluded that the information provided by the licensee was sufficient to address the information need request.
9	**<u>Combined Effect Flood – Steady-state Assumption</u>** <u>Background</u>: The evaluation of the controlling combined effect flood uses a steady-state HEC-RAS [river analysis system] model (Entergy, 2015). <u>Request</u>: Discuss the rationale for utilizing a steady-state flow analysis versus an unsteady-state analysis in the HEC-RAS model and what differences (in terms of maximum water elevations and velocities) may be expected should an unsteady-state analysis be considered. Describe how the use of the steady-state flow approach in the controlling combined effect flood reevaluated flood analysis allows for the estimation of warning time, duration of inundation and time of recession. Summarize how the values were calculated.	The licensee's response (Entergy, 2016a) clarified the controlling combined effect flood, which the licensee refers to as "H.3 – Floods along the shores of Open and Semi-Enclosed Bodies of Water". This scenario includes the combination of the PMSS with coincident wind-wave effects, 25–year flood in the Mississippi River, and levee failure (Alternative 3 of H.3). The licensee's consideration of Mississippi River Project Design Flood (PDF) used the USACE PDF flowrate, consistent with other NPPs upstream of the Mississippi River. The licensee's rationale for using steady-state simulation for PMF/Dam Failure was that the historic storm hydrographs on the Mississippi River show a wide and flat peak, similar to a steady-state assumption.

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		The staff performed sensitivity analysis to determine the differences between maximum water elevations using an unsteady-state analysis. The licensee stated that for warning and inundation times: • Calculation of warning time begins when water level reaches 24 ft. MSL. • Reference was made to the warning time for combined effect Storm 402c Based on the staff's sensitivity analysis and the staff's review of licensee's response to the information need request, the NRC staff concluded that the licensee's rationale for use of a steady state was sufficient to address the information need request. The licensee did not provide warning, inundation, or recession times during the audit and the licensee indicated that information would be submitted as part of a later assessment in the mitigating strategy assessment or the focused evaluation stage. The NRC staff notes that subsequent to the audit, the licensee has submitted the "Mitigation Strategies Assessment for Flooding Report" (Entergy, 2016) with the necessary flood duration parameters. The MSA was reviewed by staff, and the associated effects and flood event durations were found to be reasonable and acceptable for use in the MSA and have been appropriately considered in the MSA (NRC, 2017).
10	**PMF/Dam Failure – Ineffective Flow Areas** Background: The licensee's evaluation of flooding along streams and rivers and due to upstream dam failures uses ineffective flow areas for regions outside and below the left descending levees of the Mississippi River. While the documentation in the	The licensee explained that the HEC-RAS configuration included two inter-connected reaches (Entergy, 2106). Right and left areas were defined as if looking downstream. Ineffective flow areas were used in areas where overtopping of levees would not be expected to occur.

	FHRR (Entergy, 2015) and WSES PMF Calculation Package (AREVA Document No. 32-9226996-000) (AREVA, 2015c) provides a description of the use of ineffective flow areas, no justification was provided. In addition, since the calibrated and validated models do not overtop the left descending levees, model performance when using these ineffective flow areas was not tested. Request: Describe and provide justification for how the ineffective flow areas are used in HEC-RAS for steady flow modeling and how the use of this modeling feature affects the conservativeness of the evaluation, especially considering the steady-state flow assumption and the fact that the coupled river system model has not been fully validated.	The HEC-RAS reaches are: a) the Mississippi River and the region east of the river's left levee, and b) the floodplain west of the river's right levee. WSES is separated from the Mississippi River by the right levee (with top elevation 29.25 ft MSL). The right and left reaches are interconnected if the right levee is overtopped. Mississippi River water encounters WSES if a right levee failure occurs. The licensee stated that the Mississippi River water elevation cannot significantly exceed the levee top elevation due to expansive spreading that would occur in that event. Two ineffective flow areas along east of the Mississippi River left levee exist. The licensee conducted sensitivity analysis by removing the ineffective flow areas and yielded the following results: • PMF o +0.1 ft. in Mississippi River o -0.5 ft. in Atchafalaya Floodplain • PMF + Dam Failure o +0.3 ft. in Miss. R. (31.2 ft. MSL) o -0.4 ft. in Atchafalaya Floodplain The calibration and validation runs did not overtop the levees. Use of ineffective flow areas was judged to be conservative. The licensee found that excluding these areas (i.e. treating them as ineffective flow areas) resulted in reduced WSES flood elevations. The licensee's sensitivity analysis considered the combination of a reduced weir coefficient (0.4) with the removal of the ineffective flow areas. The sensitivity demonstrated by the licensee shows little change in the floodplain. The staff also performed sensitivity runs with a quasi-steady state model. Based on the review of the licensee's response and the staff's sensitivity analysis, the NRC staff considers the ineffective flow area assumption to be acceptable for determining flooding elevation and velocity and concluded that the information

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		provided by the licensee was sufficient to address the information need request.
11	**PMF/Dam Failure – Lateral Structure Weir Coefficient** Background: The HEC-RAS model used to evaluate flooding along streams and rivers, and upstream dam failures was calibrated using historical observation data and validated using the USACE PDF, both of which represent events which did not overtop levees, meaning that these model features were not tested, and the ability of the final model to predict flow distribution between the Mississippi River and Atchafalaya River floodplain is largely unknown (see FHRR and WSES PMF Calculation Package [AREVA Document No. 32-9226996-000]) (Entergy, 2015; AREVA, 2015c). In particular, as a major driver of flow distribution in the model, the selected weir coefficient value is unverified and is based on typical inline broad-crested weir coefficient values of 2.6 to 3.1. Based on the HEC-RAS simulation for flooding in streams and rivers, the selected upstream flows entering the Mississippi and Atchafalaya Rivers at River Station (RS) 320 are 6,800,000 cubic feet per second (ft^3/s) and 875,000 ft^3/s, respectively. Downstream at RS 130 (WSES location), the majority of the flow has been routed to the Atchafalaya River, with 5,875,000 ft^3/s in the Atchafalaya River and 1,800,000 ft^3/s in the Mississippi River. Based on these results, significant flow is routed from the Mississippi River to the Atchafalaya River via overtopping of the right	The licensee's response stated (Entergy, 2016) that "The selection of a weir coefficient of 2.6 is supported by the Brunner literature (Brunner, 2014)." The licensee provided in the response a table from the literature. The licensee stated that the levee was over 3 ft. high and, according to the table provided, the range of weir coefficient for such levees is 1.5 to 2.6. Thus, the licensee stated that the selected weir coefficient of 2.6 was within the expected range based on the literature. The staff performed a sensitivity analysis using a steady state model to test a reduction of the lateral weir coefficient. Based on the staff's sensitivity analysis and the staff's review of licensee's response to the information need request, the NRC staff concluded that the information provided by the licensee was sufficient to address the information need request.

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	descending levee (modeled as a Lateral Structure in HEC-RAS). Although presented in the context of the recently released 1-D/2-D version of HEC-RAS, Brunner (2014) discusses a common issue associated with modeling flow transfer from a river to a floodplain in which too much flow is transferred when using typical inline weir coefficients. As a solution, Brunner (2014) provides guidelines for weir coefficient values for various lateral weir scenarios, including modeling natural high ground barriers using weir coefficients of 0.5 to 1.0 and modeling overland flow escaping a main river using weir coefficients of 0.2 to 0.5, much lower than the selected value of 2.6. Based on the discussion provided in this literature and the fact that significant flow transfer to the floodplain occurs, the use of lower weir coefficients may be justified. <u>Request</u>: Discuss the rationale for selecting a weir coefficient of 2.6 and the potential for this value to inadequately represent flow transfer to the floodplain. Considering the guidance presented in the Brunner (2014) literature, describe whether lower weir coefficients may be more appropriate, especially considering the steady-state flow assumption and the fact that the coupled river system model has not been fully validated.	
12	**<u>Dam Failure – Peak Flow Attenuation</u>** <u>Background</u>: The evaluation of flooding due to upstream dam failures assumes that attenuation occurs between the most-downstream dam failed and the WSES location (see FHRR and WSES PMF Calculation Package (AREVA Document No.	The licensee stated in their response (Entergy, 2016) the use of peak flow attenuation for dam failure flooding evaluation reflects NRC's JLD-ISG-2013-01 (NRC, 2013) for dam failure. The licensee's conservatism is present through the assumptions used to simulate two upstream "hypothetical" dams and the empirical breach outflow assumed for these dams. The

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	32-9226996-000)) (Entergy, 2015c). The peak breach flows calculated for the Arkansas-White-Red Region and Lower Mississippi Region hypothetical dams are roughly 11.3 million ft^3/s and 5.5 million ft^3/s, respectively. After accounting for attenuation using the U.S. Bureau of Reclamation (USBR) method, the peak breach flows are 34,000 ft^3/s (0.3 percent of the total flow) and 280,000 ft^3/s (5.1 percent of the total flow), respectively. These hypothetical dam failures are assumed to occur due to overtopping coincident with the PMF. Consequently, the combined attenuated peak breach flows are added to the PMF flows as a steady-state flow for simulating dam failure flooding impacts. <u>Request</u>: Justify the application of the USBR attenuation method for peak flow attenuation, and describe how the historical data used to develop the USBR empirical equation compares with the postulated dam failure being simulated.	licensee also stated that historical dam failure characteristics support greater attenuation associated with wider floodplains. Part of the staff's initial concern was that historical dam failure attenuation had not been documented for attenuation percentages as low as those used for WSES. The rationale described by the licensee appears to make sense, though attenuation of 0.3% of peak flow was used for the Arkansas-White-Red Region. The lowest value reported in the USBR literature used to derive the equation is around 3% at a distance of about 70 miles downstream of the dam or the location where the peak discharge was recorded. The licensee response discusses the larger distances between the dams and the WSES site than those discussed in the USBR literature. The licensee presented a literature review of dam breach flow attenuation and concluded that the use of the USBR equation is appropriate. Guidance in JLD-ISG-2013-01 (NRC, 2013) states "Regression equations for attenuation provided in USBR (1982) may be used, but should be tested against available models and/or studies to justify their applicability to the river/floodplain system." The licensee did not provide reference to previous use of this method for this river/floodplain system. The staff reviewed additional literature, which detailed that significant attenuation could reasonably occur at the site. Based on the staff's independent literature review and the staff's review of licensee's response to the information need request, the NRC staff concluded that the information provided by the licensee was sufficient to address the information need request.
13	**<u>Dam Failure – Model Instability</u>** <u>Background</u>: Section 3.3.2 of the FHRR (Entergy, 2015a) (also see WSES PMF Calculation Package, AREVA Document No. 32-9226996-000 [Entergy, 2015c]) describes the dam failure flooding results and indicates that, initially, dam failure peak breach	The licensee stated (Entergy, 2016) that the HEC-RAS model for the site is steady state with a split flow between the Mississippi and Atchafalaya rivers. The licensee acknowledged the instability issue and conducted sensitivity analysis to demonstrate that the results presented

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	flow was added to the upstream end of the Mississippi River in HEC-RAS; however, the additional flow resulted in HEC-RAS model instabilities (including decreasing the WSE in the Mississippi River despite increases in flow). Since the model is run in a steady-state mode, the increased flow added to the upstream boundary of Mississippi River is routed in the model to the Atchafalaya River, which does not seem to be technically reasonable. The licensee's solution was to instead add the dam failure flow to the upstream end of the Atchafalaya River, which results in a minor increase in elevation within the Atchafalaya River and no change in the Mississippi River. Based on the licensee's unsuccessful attempt to route the dam failure flow through the upstream end of the Mississippi River, it would appear that there may be an issue with the way in which flow is routed between the two river systems (see Information Need No.10). Sensitivity analysis conducted by NRC staff using a lower lateral weir coefficient value was able to avoid the model instability reported by the licensee. Request: Describe the factors which may contribute to the model instability observed when increasing flow at the upstream end of the Mississippi River, and justify the use of a model which demonstrates instability despite relatively minor changes in boundary conditions. Provide justification for the selected approach to routing dam breach flows, which resulted in no change in elevations in the Mississippi River at WSES despite an over 4 percent increase in flow that should have entered the system. Provide alternative modeling or engineering calculations which more	(from an unstable model) were more conservative than those displaying more stability (i.e., the floodplain peak WSE was higher/more conservative). The licensee's results are similar to those obtained by staff. The sensitivity of the model within the Atchafalaya Floodplain is insignificant relative to the noted instability. The licensee references USACE, 2010 and NRC, 2013 in the response.

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	appropriately demonstrate the flooding impacts including WSE, velocities, and timing issues, associated with the increased flow from dam failure.	
14	**<u>Combined Effects – Bounding Storm Selection</u>** <u>Background</u>: According to Section 3.9.4 of the FHRR (Entergy, 2015a), "the Controlling Combined Effect Flood (CCEF) scenario is considered to be the result of H.3, Storm 402c." However, review of the results for the Storm 302 evaluations indicates Storm 302 bounds Storm 402c in terms of maximum WSE, maximum flow depth, maximum velocity, and time to maximum flow depth (FHRR, Table 3-29). <u>Request</u>: Explain why the results from the Storm 402c evaluation are used for the Controlling Combined Effect Flood, considering Storm 302 produces more severe flooding impacts.	The licensee's response (Entergy, 2016a) referenced the response to Information Need No. 4. The licensee states in the response that "Results for Storm 302 and Storm 402c are discussed in the FHRR to illustrate the steps used in the HHA process." The licensee references AREVA Document Nos. 32-9227036-000 (AREVA, 2015b) and 32-9227002-000 (AREVA, 2015e). Storm 302 (offshore decay, no post-landfall, onshore decay) flood hazards indicated flood impacts to SSCs. Storm 402c (offshore and post landfall, onshore decay) was examined as HHA refinement to Storm 302. The licensee states that rates of decay are provided in AREVA Document Nos. 32-9227036-000 and 32-9227002-000. The rates are stated as being evaluated against historical data and as being more conservative than published rates. The offshore decay rate was based on historical data. The HHA approach was used by the licensee to evaluate combined effects floods at WSES as outlined in NUREG/CR-7046 (NRC, 2011) • Storm 302 considered offshore decay, onshore decay of PMH, indicating flood impacts to SSCs. • Storm 402c considered offshore decay, post landfall, and onshore decay that is used for controlling combined effect flood • The simulations were performed in a step-wise manner to assess the sensitivity of the resulting surge elevations at the Waterford site to hurricane intensity decay. The NRC staff reviewed the information in response to licensee's allowance for wind intensity decay and concluded

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		that the information provided was sufficient to resolve the information need request. However, the staff issued a follow-up information need regarding Storm 401a and why that storm was not considered after reviewing the licensee's response (see Information Need No. 19).
15	<u>**Combined Effects – Outflow Elements**</u> <u>Background</u>: As described in Section 3.9.3.3 of the FHRR (Entergy, 2015a) (also see Combined Effects Calculation Package, AREVA Document No. 32-9227036-000 AREVA, 2015b]), FLO-2D outflow elements were modeled as stage control elements by specifying time-stage relationships along the model computational boundary. One curve was established for outflow elements along the Mississippi River, with a different curve used along the remaining model boundary, representing the Atchafalaya floodplain. Based on review of AREVA Document No. 32-9227036-000 (AREVA, 2015b), Figure 41, the time-stage relationships used in FLO-2D do not match the output hydrographs from the PMSS with 25-year river flood simulations. Most importantly, based on the curves used in FLO-2D and review of the FLO-2D time-depth output, the WSES site is dry when water begins to overtop the Mississippi River right descending levee. However, Figure 41 shows water elevation in excess of site grade for several hours prior to the levee being overtopped. <u>Request</u>: Provide justification for selecting the time-stage relationships used in the final FLO-2D run that starts with a dry site, despite those curves not matching with the PMSS with 25-year river flood simulation results that shows the site to be wet prior	The licensee's response (Entergy, 2016a) stated that with regard to the FLO-2D outflow hydrographs, even though the FLO-2D hydrographs start as a dry site, they reach maximum WSE at site of 24.0 ft. MSL prior to failure of levee. The hydrograph started at 1.4 ft. MSL to maintain model stability. The staff performed a sensitivity analysis to determine the impact of the time-stage relationships on the peak WSE. In addition to the staff's sensitivity analysis, the staff reviewed the licensee's response and concluded the information provided by the licensee was sufficient to resolve the information need request.

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	to overtopping. As a part of the response, consider impacts on both maximum WSE and associated effects (e.g., velocity, inundation time, etc.). If necessary, provide a sensitivity analysis to demonstrate the relative impacts of changing the time-stage curves set for FLO-2D stage control elements.	
16	**<u>Combined Effects – Levee Failure Trigger Elevation</u>** <u>Background</u>: As described in Section 6.3.3.1 of Combined Effects Calculation Package (AREVA Document No. 32-9227036-000) (AREVA, 2015b), the simulation of Combined Effects scenario H.3, Storm 402c uses a levee prescribed failure elevation of 29.4 ft. MSL, which is 0.5 ft. below the prescribed failure elevation used for scenario H.3, Storm 302 (29.9 ft. MSL) and 0.6 ft below the levee crest elevation of 28.6 ft. NAVD88. A change in this failure parameter could have impacts on flooding at WSES. <u>Request</u>: Provide justification for selecting a levee prescribed failure elevation of 29.4 ft MSL for Storm 402c as opposed to the higher elevation used for Storm 302 (29.9 ft. MSL). As a part of the response, consider impacts on both maximum WSE and associated effects (e.g., velocity, inundation time, etc.). If necessary, provide sensitivity analyses to demonstrate the relative impacts of increasing the levee prescribed failure elevation.	The licensee's response (Entergy, 2016a) refers to responses to Information Needs No. 14 and 15 regarding use of Storm 402c. The licensee indicated that the maximum stillwater elevation in the Mississippi River based on ADCIRC+SWAN simulations for Storm 402c + 25-year flood is 29.5 ft. MSL. Specifying a higher levee prescribed failure elevation is not realistic. The licensee stated the failure elevation of the levee was set to 29.4 ft. MSL for Storm 402c and was based on the maximum WSE in the Mississippi River for this storm scenario. The licensee stated in the response to Information Need No. 15, that "the prescribed levee failure elevation of 29.4 ft. MSL corresponds to a Mississippi River water surface elevation of 29.5 ft. MSL" or 0.1 ft higher than the specified levee breach elevation and 0.5 ft. below the top of the levee elevation of 29.9 ft. MSL. The licensee stated in the response that "[h]ydrologic failure of the levees were conservatively assumed to result from wave overtopping for Storm 402c even though the levees are not overtopped by the stillwater flood." The NRC staff reviewed the response and concluded the information provided was sufficient to resolve the information need request.

Information Need No.	Information Need Description	Response
17	**Combined Effects – Manning's Roughness Coefficient *(n)*** Background: Comparison of Table 3 in WSES LIP Calculation Package (AREVA Document No. 32-9226993-000) (AREVA, 2014) and Table 1 in Combined Effects Calculation Package (AREVA Document No. 32-9227036-000) (AREVA, 2015b) indicates that the same Manning's roughness *n* coefficients were used for each land cover type considered. However, review of the FLO-2D Reference Manual suggests that the selected Manning's roughness coefficients lie at the lower end of the recommended range for overland flow. In the absence of any calibration data, a conservative approach is warranted, and, as such, staff requests that model sensitivity to the selection of Manning's *n* values be tested. The staff's experiences with other sites and sensitivity runs conducted for the Waterford site indicate that use of a higher Manning's *n* value for this modeling will result in a higher predicted WSE. Request: Provide justification for selecting the Manning's *n* values used in the FLO-2D modelling. If necessary, provide sensitivity analyses for using Manning's *n* values adjusted to the upper end of the ranges recommended in the FLO-2D Reference Manual. As a part of the response, consider impacts on both predicted maximum WSE and associated effects (e.g., velocity, inundation time, etc.) at the WSES site.	The licensee's response (Entergy, 2016a) stated that the selected Manning's *n* values used in the FLO-2D modeling (AREVA, 2015b; Table 3) were based on recommended Manning's *n* values for various land cover types in the FLO-2D Reference Manual and in the Open-Channel hydraulics text book by Chow and upon engineering judgement. Depth variable Manning's Roughness Coefficients were used in the FLO-2D flood simulations. The licensee stated in the response (Entergy, 2016a) that Manning's roughness coefficients are a function of flow depth and that shallow flows (generally less than 0.5 ft.) require high coefficients to account for increased resistance to relatively greater surface roughness conditions. The Manning's roughness was prescribed for flow depths less than 0.2 ft. and half that value for flow depths between 0.2 ft. and 0.5 ft. The Manning's roughness coefficient was set to a deep flow value (flow depths of 3 ft and greater). The Manning's roughness coefficient varied for flood depths between 0.5 ft. and 3.0 ft. according to an exponential function within FLO-2D. The licensee stated that for Storm 402c, the maximum flood depths ranged from 7.5 to 8.9 ft. At these flood depths, the FLO-2D model would set the Manning's roughness coefficient to the licensee's specified deep flow value. In the response the licensee discussed the reasonable ranges of Manning's roughness coefficient as reported in the literature, as recommended for FLO-2D models and other models, and as influenced by whether the flow analysis was one- or two-dimensional. The licensee stated that the values used were appropriate. The licensee did not provide sensitivity analysis, but the staff determined that relatively minor changes resulted when varying the Manning's *n* values during its own sensitivity modeling runs.

Information Need No.	Information Need Description	Response
		The response references AREVA, 2015b; FLO-2D, 2012; and Chow, 1959. The staff reviewed the response and concluded that the information provided, in addition to the results of staff's sensitivity runs, resolved the information need request.
18	<u>**Storm Surge Analysis - Datum Conversion**</u> <u>Background</u>: The FHRR (Entergy, 215a) contains two different references related to conversion of elevations in the NAVD88 and MSL datum. a. FHRR Section 1.5 states "To convert elevations from the North American Vertical Datum of 1988 (NAVD88)-2004.65 to Mean Sea Level (MSL) (Plant Datum), 1.43 ft is added to the NAVD88-2004.65 elevation (see Appendix A)". Appendix A contains additional information on the NAVD88 and MSL conversion (Appendix includes the 1.43 ft value). b. FHRR Section 3.4.4.2.1 provides the conversion between local mean seal level (LMSL) and NAVD88: "The average LMSL to NAVD88-2004.65 adjustment for the South Louisiana region is calculated to be 0.135m (0.44 ft)." This conversion is applied in the Antecedent Water Level calculation. <u>Request</u>: Provide additional explanation of when or how each NAVD88 to MSL conversion was applied in the FHRR analyses.	The licensee confirmed (Entergy, 2016a) that to convert from NAVD88 to MSL, +1.43 ft. is added. The licensee stated that LMSL is not the same as Plant Datum (MSL). The licensee stated that the only use of the LMSL to NAVD88 was for the AWL calculation. The licensee stated in the response that "the average LMSL adjustment for the South Louisiana Region was based on the Interagency Performance Task Force report (USACE, 2006; also see AREVA, 2015b)". The conversion of LMSL to NAVD88 is not the same conversion used to convert from MSL to NAVD88. The licensee references AREVA 2015b; AREVA, 2015f; and UASCE, 2006 in this response. The NRC staff reviewed the response and concluded it is sufficient to resolve the information need request.
19	<u>**Storm Surge Analysis – Storm Selection**</u>	The licensee stated (Entergy, 2016a) that although Storm 401a results in a higher Mississippi River water level than Storm 402c, FLO-2D simulations for the levee breach analysis for

Information Need No.	Information Need Description	Response
	Background: FHRR Section 3.9.3.3 (Alternative 3, Part C) discusses the combined effects analysis for storm surge with the Probable Maximum Hurricane, 25-year river flow, Antecedent Water Level, and levee failure (Entergy, 2015a). a. The discussion states "Levee failure simulations using FLO-2D were performed for Storm 302 and Storm 402c." FHRR Table 3-35 presents ADCIRC+SWAN results for representative storms including Storms 302 and 402c. Storms 302 and 402c have storm tracks that head due north and produce maximum surge at the site (before levee failure analysis). FHRR Table 4-1 presents the results, including levee failure analysis, from Storm 402c as the Controlling Combined Effect Flood Scenario in the Reevaluated Flood Height column. b. Table 3-35 also includes results from Storm 401a, which based on Table 3-35, applies the same PMH forcing as Storm 402c other than landfall location and track angle (bearing). Storm 401a features a track that moves the storm in a northwesterly direction (-40 degrees from North). Table 3-35 indicates Storm 401a features higher maximum water levels in the Mississippi River near the Waterford site than Storm 402c	Storm 401a were not performed. The licensee determined that Storm 402c would produce higher peak WSEs at the site. The licensee references the combined effects calculation (AREVA, 2015b) to support this determination. In the response, the licensee included Table 19-1, which is an update of FHRR Table 4-1. The licensee's Table 19-1 in the response shows results based on other storm simulations that included levee breach analysis. The table focuses on the differential between the Mississippi River and site water levels. Regarding the PMF on the Mississippi River mechanism at the Waterford site, the design-basis flood height was modified to "No flooding" and the reevaluated flood height was stated as 20.0 ft. MSL at the Waterford site. Regarding the mechanism description of the Controlling Combined Flood Scenario, the licensee's update of the table included the following additional description: "PMSS from Gulf of Mexico with coincident wind-wave effects, 25-year flood in the Mississippi River, and levee failure." The original FHRR Table 4-1 included a note that the LIP hazard levels was based on an assumed pumping criteria described in FHRR Section 5; in the revised table the reference was not included. The relevant update in the information need response (Table 19-1) is the explicit statement of the components of the controlling combined flood scenario. The licensee stated that "because the flood response at the sites, after levee breach, is more dependent on the absolute differential head between the initial water elevation in the M[ississippi] R[iver] and at the site than upon the actual elevation in the M[ississippi] R[iver]". The licensee illustrated the trend of the head differential between the Mississippi River level and the site versus the change in elevation at site after breach. The staff reviewed the explanation provided by the licensee, which stated that both the water level in the Mississippi River and the water level at the site at time of breach are important.

Information Need No.	Information Need Description	Response
	31.8 ft MSL for Storm 401a versus 29.5 ft MSL for Storm 402c). Because the river water levels will propagate towards the site during the levee breach analysis (as input into the FLO-2D model), the staff notes that Storm 401a forcing could potentially produce higher maximum water levels at the site than Storm 402c under a levee failure scenario. Request: Provide discussion of why FLO-2D simulations for the levee breach analysis were not performed for Storm 401a, a storm that resulted in higher Mississippi River water levels than Storm 402c.	The licensee is deferring associated effects and flood event duration parameters to the MSA stage. The response references AREVA, 2015b and Entergy, 2015a. The staff reviewed the licensee's response and concluded that the information provided was sufficient to resolve the information need request.
20	**Flood Event Timing Parameters** Background: FHRR Section 3.1.2 (Entergy, 2015a) indicated that the LIP internal to the NPIS was not bounded by the CDB. The FHRR does not describe the flood event timing parameters (warning time, preparation time, flood duration and recession time). Warning time and preparation time is not clearly stated for the current licensing basis. The staff noted that some of this information may be provided in the OP-901-521 (Entergy, 2014) "Severe Weather and Flooding" prior to it revision as described in the FHRR. The staff also noted that warning times are utilized in the Operational Decision Making Issue implementation action plan. These procedures are mentioned in Section 5.1.2 of the FHRR as interim actions which are not equivalent to those under the current licensing basis (Entergy, 2015a).	The licensee requested to defer providing this information until the MSA stage of the review. The NRC staff notes that subsequent to the audit, the licensee submitted the "Mitigation Strategies Assessment for Flooding Report" (Entergy, 2016) with flood duration parameters. The MSA was reviewed by staff and the associated effects and flood event durations were found to be reasonable and acceptable for use in the MSA, and have been appropriately considered in the MSA (NRC, 2017).

Information Need No.	Information Need Description	Response
	Request: Provide flood event duration parameters associated with the LIP and combined event, or describe when the parameters will be provided.	
21	**Local Intense Precipitation – Site Specific PMP** The staff requests the following files be submitted on the docket for use in the staff assessment: 1. AWA SSPMP Main Report for Waterford Steam Electric Station This request is for the complete AWA ssPMP report in Adobe pdf format, including all appendices. 2. AWA ssPMP LIP Calculation Package for Waterford Nuclear Generating Station This request is for the complete calculation package for site-specific LIP calculations, including all appendices.	The NRC staff determined that a detailed review of the licensee's site specific PMP review is not needed, and thus Waterford was informed they did not need to respond to this information need request.
22	**Local Intense Precipitation – Site Specific PMP** The staff requests the following files be provided on a DVD for staff review as part of the audit: 1. The complete storm analysis information for LIP ssPMP. Provide the analysis information for all short list storms that were used for LIP ssPMP calculations (such as those reported in the previous AWA reports). The detailed storm analysis information should include: • Storm spreadsheet • Moisture inflow map	The NRC staff determined that a detailed review of the licensee's site specific PMP review is not needed.

Information Need No.	Information Need Description	Response
	• Depth-area-duration values and chart • Storm cumulative mass curve chart • Total storm isohyetal analysis map • HYSPLIT trajectory map • In-place storm representative dew point (or sea surface temperature) analysis map 2. AWA Initial Storm Long List In addition to the final storm short list, the licensee should also submit an Excel file documenting the complete initial long list storms that have been considered during the development of the LIP ssPMP. If a storm is excluded from the final short list, a brief justification should be provided. In addition, documentation should be provided to identify which long list storms have been previously evaluated by AWA and which have been newly evaluated as a part of the ssPMP study. If a subset of long list storms were included/excluded based on previous Federal Energy Regulatory Commission BOC or state PMP study conclusions, the exact reference should be clearly stated. 3. AWA Observed Hourly Dew Point Data Sheet For each short list storm, the licensee should submit an individual spread sheet documenting the hourly dew point data that were used for storm representative dew point selection (page 8, Section Storm Adjustments, item 2e in AWA PMP Development Workflow Description	

Information Need No.	Information Need Description	Response
	submitted to NRC on May 7t, 2015). If publicly-accessible dew point datum were used (e.g., NCDC ISD), the unique station identifier (e.g., USAF, WBAN, and/or ICAO) and the starting/ending dew point date and hour (used for the calculation of average 6-, 12-, or 24-hour dew points) should be clearly specified. If the selection of storm representative dew point location deviated significantly from the HYSPLIT trajectories, detailed meteorological reasoning should be provided. If sea surface temperature is used as a surrogate of surface dew point observation, the sea surface temperature observation should be provided. 4. AWA Calculation Sheet of 100-year Dew Point Climatology At locations where the 100-year dew points were derived from dew point climatology maps (i.e., moisture source before/after storm transposition), the dew point bias resulting from map smoothing should be examined. Bias is defined as the difference between the nearest gauge estimates to the smoothed map values. If the bias is sufficiently large (e.g., negative 2 F leading to 8% reduction of maximized precipitation depth), the calculation sheet of 100-year dew point at the selected gauge should be provided for review.	

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ATTACHMENT 3
Waterford Steam Electric Station, Unit 3 Tables and Figures

Table 1. Summary of Results of FLO-2D Levee Failure Analysis in WSES Combined Effect Calculation (adapted from Table 19-1 in Entergy, 2016)[1,2]

Flooding Scenario (#1)	Initial Water Elevation at Site, ft.-MSL (#2)	Mississippi River Elevation, ft.-MSL (#3)	Resulting Water Elevation at Site after Levee Breach, ft.-MSL (#4)	Head Differential between River and Site prior to Levee Breach, ft. (#5)[4]	Change in Water Elevation at Site after Levee Breach, ft. (#6)[4]
Column	2	3	4	5	6
H.2 –Water level in river at top of levee elevation and site dry	17.09	30.03	20.83	12.94	3.74
H.1 – PMF+ Upstream Dam Failure	20.53	30.03	23.38	9.5	2.85
H.3- Storm Surge + 25-yr flood – No Offshore Decay (302)	25.73	31.33	28.00	5.6	2.27
H.3- Storm Surge + 25-yr flood – Offshore Decay	24.03	29.53	25.97	5.5	1.94
Interpolated Information based on Figure 19-1 in Entergy, 2016					
H.3 Storm 401a[3]	20.53	31.93	**23.93**	11.4	**3.4**

Note:

[1] Results at the northwest corner of the Nuclear Plant Island Structure (grid element #24028) are used as representative results at the site. Ground elevation at grid element #24028 is 17.09 ft. MSL.

[2] The values in this table were converted NAVD88 to MSL by the staff.

[3] Values in the table are taken from the Waterford Steam Electric Station Combined Effects Calculation. Values in bold for Storm 401a are derived based on interpolation from plot provided in the information need response.

[4] Values in Column 5 were computed by subtracting Column 2 from Column 3. Values in Column 6 were computed by subtracting Column 2 from Column 4.

NUCLEAR REGULATORY COMMISSION REPORT FOR THE AUDIT OF ENTERGY NUCLEAR OPERATIONS, INC'S. FLOOD HAZARD REEVALUATION REPORT SUBMITTAL RELATING TO THE NEAR-TERM TASK FORCE RECOMMENDATION 2.1-FLOODING FOR WATERFORD STEAM ELECTRIC STATION, UNIT 3 DATED November 8, 2017

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