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

August 29, 2017

ANO Site Vice President
Arkansas Nuclear One
Entergy Operations, Inc.
1448 S.R. 333
Russellville, AR 72802

SUBJECT: ARKANSAS NUCLEAR ONE, UNITS 1 AND 2 - STAFF ASSESSMENT OF RESPONSE TO 10 CFR 50.54(f) INFORMATION REQUEST – FLOOD-CAUSING MECHANISM REEVALUATION (CAC NOS. MF8379 AND MF8380)

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 that licensees reevaluate flood-causing mechanisms using present-day methodologies and guidance. By letter dated September 14, 2016 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML16260A060), Entergy Operations, Inc. (Entergy, the licensee) responded to this request for Arkansas Nuclear One, Units 1 and 2 (ANO).

By letter dated December 2, 2016 (ADAMS Accession No. ML16327A494), the NRC staff sent the licensee a summary of the staff's review of the licensee's reevaluated flood-causing mechanisms. The enclosed staff assessment provides the documentation supporting the NRC staff's conclusions summarized in the letter. As stated in the letter, the reevaluated flood hazard result for local intense precipitation (LIP) is not bounded by the current design basis flood hazard. The NRC staff notes that the licensee has performed a focused evaluation for LIP as documented by letter dated May 31, 2017 (ADAMS Accession No. ML17153A280). The NRC staff will provide its assessment of the ANO focused evaluation in a separate letter.

This closes out the NRC's efforts associated with CAC Nos. MF8379 and MF8380.

Enclosure 1 transmitted herewith contains Security-Related Information. When separated from the Enclosure, this document is decontrolled.

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

Sincerely,

Joseph M. Sebrosky, Senior Project Manager
Hazards Management Branch
Japan Lessons-Learned Division
Office of Nuclear reactor Regulation

Docket Nos. 50-313 and 50-368

Enclosures:
1. Staff Assessment of Flood Hazard Reevaluation Report (non-public, Security related information)
2. Staff Assessment of Flood Hazard Reevaluation Report (public)

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

ARKANSAS NUCLEAR ONE, UNITS 1 AND 2

DOCKET NOS. 50-313 AND 50-368

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), (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 (NTTF) Report (NRC, 2011b). Recommendation 2.1 in that document recommended that the NRC 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 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) to address this recommendation.

Enclosure 2 to the 50.54(f) letter (NRC, 2012a) requested that licensees reevaluate the flood hazard 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 the NRC staff would provide a prioritization plan indicating the Flood Hazard Reevaluation Report (FHRR) deadlines for each plant. On May 11, 2012 (NRC, 2012c), the NRC staff issued its prioritization of the FHRRs.

By letter dated September 14, 2016 (Entergy, 2016), Entergy Operations, Inc. (Entergy, the licensee) provided its FHRR for Arkansas Nuclear One (ANO), Units 1 and 2. The licensee did not identify any interim actions.

On December 2, 2016 (NRC, 2016c), the NRC issued an interim staff response (ISR) letter to the licensee. The purpose of the ISR letter is to provide the flood hazard information suitable for the assessment of mitigating strategies developed in response to Order EA-12-049 (NRC, 2012b) and the additional assessments associated with NTTF Recommendation 2.1: Flooding. The ISR letter also made reference to this staff assessment, which documents the NRC staff's basis and conclusions. The flood hazard mechanism values presented in the letter's enclosures match the values in this staff assessment without change or alteration.

As mentioned in the ISR letter (NRC, 2016c), the reevaluated flood hazard results for the local intense precipitation (LIP) flood-causing mechanism are not bounded by the plant's current design basis (CDB). Consistent with the 50.54(f) letter and amended by the process outlined in COMSECY-15-0019 (NRC, 2015), Japan Lessons-Learned Division (JLD) Interim Staff

Enclosure 2

Guidance (ISG) JLD-ISG-2012-01, Revision 1 (NRC, 2016a) and JLD-ISG-2016-01, Revision 0 (NRC, 2016b), the NRC staff anticipates that the licensee will perform and document a focused evaluation for LIP and associated site drainage that assesses the impact of the LIP hazard on the site and evaluate and implement any necessary programmatic, procedural or plant modifications to address this hazard exceedance. The NRC staff notes that the licensee has performed a focused evaluation for LIP as documented by letter dated May 31, 2017 (Entergy, 2017a). The NRC staff will provide its assessment of the ANO focused evaluation in a separate letter.

2.0 REGULATORY BACKGROUND

2.1 Applicable Regulatory Requirements

As stated above, Enclosure 2 to the 50.54(f) letter (NRC, 2012a) requested that licensees reevaluate flood hazards at their sites using present-day methods and regulatory guidance used by the NRC staff when reviewing applications for ESPs and COLs. This section of the staff assessment describes present-day regulatory requirements that are applicable to the FHRR.

Sections 50.34(a)(1), (a)(3), (a)(4), (b)(1), (b)(2), and (b)(4), of 10 CFR, describe the required content of the preliminary and final safety analysis report, including a discussion of the plant 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 final safety analysis report.

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 "design bases" 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 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" (CLB) 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 updated final safety analysis report (UFSAR).

The licensee's commitments made in docketed licensing correspondence, which remain in effect, are also considered part of the CLB.

Present-day regulations for reactor site criteria (Subpart B to 10 CFR Part 100 for site 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

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 (NRC, 2012a) requested, in part, that 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.

2.2.1 Flood-Causing Mechanisms

Attachment 1, Enclosure 2 of the 50.54(f) letter discusses the flood-causing mechanisms for the licensee to address in the FHRR (NRC, 2012a). Table 2.2-1 lists the flood-causing mechanisms the licensee should consider and lists the corresponding Standard Review Plan (SRP) (NRC, 2007) section(s) and applicable ISG documents containing acceptance criteria and review procedures.

2.2.2 Associated Effects

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

- Wind waves and runup 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 effects flood." It should also be noted that for the purposes of this staff assessment, the terms "combined effects" and "combined events" are synonyms. 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, "Areas of Review" (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, 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), then the NRC 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 are plausible combined events and should be considered.

2.2.4 Flood Event Duration

Flood event duration was defined in JLD-ISG-2012-05 (NRC, 2012d) 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 CDB flood hazard elevation for all flood-causing mechanisms, the 50.54(f) letter (NRC, 2012a) 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; and

- Perform an integrated assessment to: (a) evaluate the effectiveness of the CLB (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 CDB flood hazard for each flood-causing mechanism at the site, licensees are not required to perform an integrated assessment. COMSECY-15-0019 (NRC, 2015) outlines a revised process for addressing cases in which the reevaluated flood hazard is not bounded by the plant's CDB.

The revised process describes an approach in which licensees with a LIP hazard exceeding their CDB flood will not be required to complete an integrated assessment, but would instead perform a focused evaluation. As part of the focused evaluation, licensees will assess the impact of the LIP hazard on their sites and then evaluate and implement any necessary programmatic, procedural, or plant modifications to address this hazard exceedance. For other flood hazard mechanisms that exceed the CDB, licensees can assess the impact of these reevaluated hazards on their site by performing either a focused evaluation or a revised integrated assessment (NRC, 2015 and NRC, 2016c).

3.0 TECHNICAL EVALUATION

The NRC staff reviewed the information provided for the flood hazard reevaluation of the ANO, Units 1 and 2 site (Entergy, 2016). 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.

To provide additional information in support of the summaries and conclusions in the ANO FHRR, the licensee made several calculation packages available to the NRC staff. The NRC staff did not directly rely on these calculation packages in its review; they were found only to expand upon and clarify the information provided in the ANO FHRR, and so those calculation packages were not docketed or cited. The NRC staff's review and evaluation are provided below.

The ANO FHRR (Entergy, 2016) provided elevations using two different vertical datum's, the North American Vertical Datum of 1988 (NAVD88) and the National Geodetic Vertical Datum of 1929 (NGVD29), also referred to as mean sea level (MSL). Unless otherwise stated, all elevations in this document are given with respect to NGVD29.

3.1 Site Information

The 50.54(f) letter (NRC, 2012a) requested that relevant SSCs important to safety be included in the scope of the hazard reevaluation. The licensee included this pertinent data concerning these SSCs in the FHRR (Entergy, 2016). The NRC staff reviewed and summarized this information as follows in the sections below.

3.1.1 Detailed Site Information

The ANO site (Figure 3.1-1) is located on the Arkansas River near Russellville, Arkansas. The site is located at approximately river mile 210 just upstream of Dardanelle Lock and Dam. The site is positioned on a peninsula with an area of approximately 2,600 acres in size and is predominately at an elevation of 400 feet (ft.) with some locations exceeding 500 ft. MSL in elevation.

The northern portion of the site near Unit 2 is at a higher elevation, however, both units have a finished floor elevation of 354 ft. MSL. Site drainage is provided by a system of catch basins, surface drainage ditches, and subsurface storm drains. Surface drainage is constricted in some locations by the perimeter Vehicle Barrier System (VBS) that fully encompasses the site and is generally about 4 ft. high. There is a gap in the VBS for the intake canal, the discharge canal, the northwest access road, and several pedestrian openings on the south access road southeast of the intake building.

Table 3.0-1 of this assessment summarizes the controlling reevaluated flood-causing mechanisms, including associated effects, that the licensee computed to be higher than the finished floor elevation.

3.1.2 Design-Basis Flood Hazards

The CDB flood levels are summarized by flood-causing mechanism in Table 3.1-1. The NRC staff reviewed the information provided in the ANO FHRR (Entergy, 2016) and determined that sufficient information was provided to be responsive to Enclosure 2 of the 50.54(f) letter (NRC, 2012a).

3.1.3 Flood-Related Changes to the Licensing Basis

The licensee stated that there had been no changes to the licensing basis. The NRC staff reviewed the information provided in the ANO FHRR (Entergy, 2016) and determined that sufficient information was provided to be responsive to Enclosure 2 of the 50.54(f) letter (NRC, 2012a).

3.1.5 Changes to the Watershed and Local Area

The McClellan-Kerr Arkansas River Navigation System was completed in 1970. This provided stability to the course of the Arkansas River, reducing any potential for meandering. The NRC staff reviewed the information provided in the ANO FHRR (Entergy, 2016) and determined that sufficient information was provided to be responsive to Enclosure 2 of the 50.54(f) letter (NRC, 2012a).

3.1.6 Current Licensing Basis Flood Protection and Pertinent Flood Mitigation Features

The SSCs important to safety are protected from the CDB flood either by their elevation or due to their being located inside reinforced concrete Seismic Class 1 structures. These structures have built-in flood protection features such as watertight doors and watertight penetrations for piping and electrical components. The flood protection capability is preserved by inspection and maintenance procedures for the flood protection features and components (Entergy, 2016).

Both ANO, Units 1 and 2, have adverse weather procedures to be taken due to different flood levels at the intake structure for each unit. These procedures specify plant actions to be taken in the event of flooding. The NRC staff reviewed the information provided in the ANO FHRR (Entergy, 2016) and determined that sufficient information was provided to be responsive to Enclosure 2 of the 50.54(f) letter (NRC, 2012a).

3.1.7 Additional Site Details to Assess the Flood Hazard

The licensee provided electronic copies of input/output files related to flood hazard reevaluations (Entergy, 2016b).

3.1.8 Results of Plant Walkdown Activities

The 50.54(f) letter (NRC, 2012a) requested that licensees plan and perform plant walkdown activities to verify that current flood protection systems are available, functional, and implementable. Other parts of the 50.54(f) letter asked the licensee to report any relevant information from the results of the plant walkdown activities (NRC, 2012a).

By letter dated November 27, 2012 (Entergy, 2012), as supplemented by letters dated November 26, 2013 (Entergy, 2013), and May 15, 2014 (Entergy, 2014), the licensee submitted the Flooding Walkdown Reports for the ANO site. On June 27, 2014 (NRC, 2014), the NRC staff issued its assessment of the Walkdown Report, which documented its review of that licensee action and concluded that the licensee's implementation of the flooding walkdown methodology met the intent of the 50.54(f) letter.

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

The licensee reported in its FHRR that the reevaluated flood hazard for LIP is based on a maximum stillwater-surface elevation that are provided in Table 4.1-1. As noted in Section 2.2 of the ANO FHRR (Entergy, 2016), flood elevations due to LIP were not specifically evaluated as part of the CDB flood hazard evaluation, but were identifies as being screened out as a flood hazard due to the height of flood protections at ANO.

The licensee used the results of a site specific probable maximum precipitation (PMP) study for the ANO site. This study was conducted using procedures found in Hydrometeorological Report No. 51 (HMR-51) and HMR-52 (NOAA, 1978 and NOAA, 1982). The study included observed storms associated with Mesoscale Convective System and individual storms. Storms were included from HMR-33 (U.S. Weather Bureau, 1956), HMR-51 (NOAA, 1978), and recent storms up through April 2010. The outcomes of this study are: 1) high-resolution precipitation grids; and 2) various duration Depth-Area-Duration information (Entergy, 2016).

3.2.1 Model Inputs

The licensee used two different models for their analysis of LIP and site drainage system. The first model was FLO-2D [two dimensional], which was used for their LIP analysis. The second model was Hydrologic Engineering Center - Hydrologic Modeling System (HEC-HMS), which was used to model the water surface elevation in the Emergency Cooling Pond (ECP).

3.2.1.1 FLO-2D LIP Model

The FLO-2D is a two-dimensional hydrodynamic model that uses shallow water equations to route storm water over the site. Information used for creating the model inputs were digital elevation models developed from light detection and ranging along with records, such as as-built drawings and new surveys of the site. The licensee performed spot checks of the elevation values used in FLO-2D by comparing them with site survey data. The FLO-2D model domain encompassed an area of approximately 812 acres. The licensee used a 20 ft. by 20 ft. grid element size.

In order to identify the flow site flow pattern, the ANO site was first modelled in FLO-2D without including the effects of the VBS. Based on this flow pattern and to ensure a conservative result, vehicle barriers that would direct flow away from the site were excluded in the subsequent model(s), while vehicle barriers that captured flow were included in the subsequent model(s). Openings in the levees were included to account for roadways and pedestrian access points. Additionally, barriers near the intake structure were included in the model with the same configuration as the VBS (Entergy, 2016). The licensee also assumed all drainage system components were either non-functional or clogged during the event and ignored losses from infiltration (Entergy, 2016).

The licensee used Manning's roughness coefficients ranging from 0.02 for concrete or paved areas to 0.40 for wooded areas. The licensee used the depth variable roughness option in the FLO-2D model, which will change the user specified roughness value and vary the Manning's roughness coefficient based on depth at a particular grid cell (Entergy, 2016).

Buildings were represented in the model as artificially elevated grid elements. To ensure that the model properly represents runoff from the building rooftops, the grid elements used to represent buildings was increased by at least 5 ft. from the surrounding typography (Entergy, 2016).

The licensee set the initial water surface elevations (WSE) for the surrounding bodies of water to their normal pool elevations values. Lake Dardanelle, the intake, and discharge canal initial WSEs were set to 338 ft. NGVD29 and the ECP initial WSE was set to 347 ft. NGVD29 (Entergy, 2016).

The licensee used the results of a site specific PMP study for the ANO site. This study was conducted using procedures found in HMR-51 and HMR-52 (NOAA, 1978 and NOAA, 1982). The study included observed storms associated with Mesoscale Convective System and individual storms. Storms were included from HMR-33 (U.S. Weather Bureau, 1956), HMR-51 (NOAA, 1978), and recent storms up through April 2010. The outcomes of this study are: 1) high-resolution precipitation grids; and 2) various duration Depth-Area-Duration information (Entergy, 2016).

Although the licensee used a site specific PMP study for the ANO site, the NRC staff performed an independent analysis of the site using the same FLO-2D model but using PMP values based on HMR-51 and HMR-52. The difference in the flood elevations were minimal at all important-to-safety structures. Since the difference in flood elevations were minimal, the NRC staff did not perform a review of the licensee's site specific PMP.

The FLO-2D model outputs for maximum WSEs, depths, and velocities were provided by the licensee in its FHRR. The reevaluated water surface elevations are tabulated for various buildings and other locations of interest, such as door openings, in Table 4.1-1. The approaches used to develop the inputs to the FLO-2D model were reviewed by the NRC staff and were found to be with current and accepted methods. Additionally, the NRC staff performed a confirmatory FLO-2D model run of the LIP scenario provided by the licensee and confirmed the licensee's results.

3.2.1.2 HEC-HMS Model

The licensee stated that a very small time step would need to be applied in the FLO-2D model to accurately estimate the water surface elevation in the ECP. To avoid this issue, the licensee used HEC-HMS to estimate the maximum flood elevation in the ECP.

The licensee developed two HEC-HMS models, one "simple" model with conservative inputs and a more complex model using more realistic inputs. The licensee's "simple" model used the Soil Conservation Service unit hydrograph method with a lag time of 6 minutes and a curve number of 99, representing an impervious surface. The NRC staff reviewed the methodology used by the licensee and performed independent calculations using HEC-HMS with the same input parameters specified by the licensee in their more conservative "simple" model. The NRC staff confirmed the peak water surface elevation in the ECP obtained by the licensee.

3.2.2 Conclusion

The NRC staff confirmed the licensee's reevaluation of the hazard from LIP used present-day methodologies and regulatory guidance. The NRC staff also confirmed the licensee's conclusion that the reevaluated flood hazard for LIP was not bounded by the CDB flood hazard. Therefore, the NRC staff expects that the licensee will submit a focused evaluation for LIP.

3.3 <u>Streams and Rivers</u>

Two scenarios are discussed in the licensee's CDB as part of the Streams and Rivers flood-causing mechanism (see Table 3.1-1; Entergy, 2016). The first scenario is from a Probable Maximum Flood (PMF) in the Arkansas River. The CDB elevation for this scenario is a stillwater elevation of 358.0 ft. (see Table 3.1-1). This CDB scenario included calculation of wave runup, however the runup and the resulting maximum water level at the ANO site are discussed in Section 3.4 below. [[

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Per Interagency Agreement NRC-HQ-13-I-03-0021, the U.S. Army Corps of Engineers (USACE) assisted the NRC in determining the safety significance of hydrologic and geotechnical issues and other features associated with dams that may affect the safe, reliable operation of downstream or nearby nuclear power plants. [[

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A summary of the results from the USACE were provided to the licensee in a letter dated March 21, 2016 (NRC, 2016d). The licensee adopted these values in its FHRR.

Based on review of the licensee's information, the NRC staff found that the licensee's reevaluated stillwater elevation for the Arkansas River PMF equals (i.e., is bounded by) the CDB stillwater elevation of 358.0 ft. Other scenarios that are part of stream and rivers CDB shown in Table 3.1-1 and associated with the Arkansas River, including waves/runup, are discussed in Section 3.4 below.

3.4 <u>Failure of Dams and Onsite Water Control/Storage Structures</u>

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3.5 <u>Storm Surge</u>

The licensee reported that the reevaluated hazard for storm surge-related flooding effects are not applicable at the ANO site (Entergy, 2016). This flood-causing mechanism is not discussed in the licensee's CDB.

The licensee stated that ANO is located on the hydrologically-controlled Arkansas River with several downstream dams that would stop the propagation of any storm surge from the Gulf of Mexico. The licensee also noted that hydrologic features around the site, including the Dardanelle Reservoir, are too narrow and meandering to generate a storm surge.

The NRC staff reviewed the information provided by the licensee and agrees that a storm surge event at the ANO site is not likely due to the inland location. The NRC staff confirmed the licensee's conclusion that the storm surge flood-causing mechanism could not inundate the ANO site. Therefore, the NRC staff determined that flooding from storm surge does not need to be analyzed in a focused evaluation or a revised integrated assessment.

3.6 Seiche

The licensee reported that the reevaluated hazard for seiche-related flooding effects are not applicable at the ANO (Entergy, 2016). This flood-causing mechanism is not discussed in the licensee's CDB.

The licensee considered the potential for seiche flooding on Lake Dardanelle, the ECP, intake canal, and discharge canal. The licensee conducted a literature review to identify historical seiche, estimated the natural periods of oscillation in the bodies of water using Merian's formula, and compared the natural oscillation period to the period of potential forcing mechanisms to determine the potential for resonance. The licensee concluded that the natural periods of the bodies of water do not align with the period of the external forcing mechanisms, therefore seiche is unlikely to occur at the ANO site.

The NRC staff reviewed the information provided by the licensee, and agrees that a seiche event at the ANO site is not likely due to the inland location. The NRC staff confirmed the licensee's conclusion that the seiche flood-causing mechanism could not inundate the ANO site. Therefore, the NRC staff determined that flooding from seiche does not need to be analyzed in a focused evaluation or a revised integrated assessment.

3.7 Tsunami

The licensee reported that the reevaluated hazard for tsunami-related flooding effects are not applicable at the ANO site. This flood-causing mechanism is not discussed in the licensee's CDB.

The licensee stated that although the ANO site is located inland from the Gulf of Mexico and therefore not susceptible to oceanic tsunami, there is the potential for tsunami on the Dardanelle Reservoir. The licensee's evaluation of tsunami within the Dardanelle Reservoir included an assessment of the earthquake, surficial landslide, and subaqueous landslide potential for triggering a tsunami. The licensee concluded that there are no tsunamigenic mechanisms in the vicinity of the ANO site that would produce a tsunami that would impact the site.

The NRC staff reviewed the information provided by the licensee, and agrees that a tsunami event at the ANO site is not likely due to the inland location. The NRC staff confirmed the licensee's conclusion that the tsunami flood-causing mechanism could not inundate the ANO site.

Therefore, the NRC staff determined that flooding from tsunami does not need to be analyzed in a focused evaluation or a revised integrated assessment.

3.8 Ice-Induced Flooding

The licensee reported that the reevaluated flood hazard for ice-induced flooding effects are negligible at the ANO site. This flood-causing mechanism is not discussed in the licensee's CDB.

The licensee followed the guidance in NUREG/CR-7046 to evaluate the potential for ice-induced flooding at the ANO site. The licensee consulted the USACE Ice Jam database (USACE, n.d.) to determine historical ice events on the Arkansas River near the ANO site; no ice jams were recorded in the ANO site vicinity since the completion of the McClellan-Kerr-Arkansas River Navigation System in 1970. The licensee identified historical ice jams upstream of the ANO site and determined that the water depth from an upstream ice jam resulted in a flood elevation of 349.3 ft. NGVD29 at the ANO site, which is below the site grade of 353 ft. NGVD29 and well below the CDB maximum stillwater elevation 361 ft. NGVD29 for a PMF in the Arkansas River. Downstream ice jams were unlikely due to the USACE oversight and maintenance of the navigable channel. Therefore, the licensee concluded that the impact of ice-induced flooding on the ANO site is negligible.

The NRC staff independently searched the USACE Cold Regions Research and Engineering Laboratory Ice Jam Database (USACE, n.d.-a) for current and historical ice jams near ANO site and found no record of ice jams in the vicinity.

The NRC staff reviewed the licensee's findings in the ANO FHRR and confirmed the licensee's conclusion that ice-induced flooding is a negligible flooding mechanism at the ANO site. Therefore, the NRC staff confirmed the licensee's conclusion that the ice-induced flooding mechanism could not inundate the ANO site. Therefore, the NRC staff determined that ice-induced flooding does not need to be analyzed in a focused evaluation or a revised integrated assessment.

3.9 Channel Migrations or Diversions

The licensee reported in the ANO FHRR that the reevaluated hazard for channel migrations or diversions is not applicable to the ANO site (Entergy, 2016). This flood-causing mechanism is not described in the licensee's CDB

The licensee used historical records and present-day channel observations to determine the potential for channel migration or diversion. The licensee noted that although there is the potential for channel migration near the ANO site, the ANO site is located on the bank that is less susceptible to erosion based on the historical channel migration pattern along the Arkansas River. Furthermore, the licensee noted that the ANO site is protected from channel migration or erosion by a point bar landform along the peninsula. Additionally, the USACE maintains navigable conditions on the Arkansas River near the site, which involves dredging, revetments, and dikes to minimize channel diversions.

The NRC staff reviewed the basin topography and noted there was no evidence of channel migration or diversion along nearby streams or tributaries that could affect the site. The NRC staff reviewed the information provided by the licensee and confirmed the licensee's conclusion that the flood hazard from channel migrations or diversions is not a plausible flooding mechanism at the ANO site. Therefore, the NRC staff determined that flooding from channel migrations or diversions does not need to be analyzed in a focused evaluation or a revised integrated assessment.

4.0 REEVALUATED FLOOD HEIGHT, EVENT DURATION, AND ASSOCIATED EFFECTS FOR HAZARDS NOT BOUNDED BY THE CDB

4.1 Reevaluated Flood Height for Hazards Not Bounded by the CDB

Section 3 of this staff assessment documents the NRC staff review of the licensee's flood hazard water height results. Table 4.1-1 contains the maximum flood height results, including waves and runup, for flood mechanisms not bounded by the CDB. The NRC staff agrees with the licensee's conclusion that the LIP mechanism is the only flood-causing mechanism not bounded by the CDB.

The NRC staff notes that the licensee has performed a focused evaluation for LIP as documented by letter dated May 31, 2017 (Entergy, 2017a). The NRC will provide its assessment of the ANO focused evaluation in a separate letter.

4.2 Flood Event Duration for Hazards Not Bounded by the CDB

The NRC staff reviewed information provided in ANO's 50.54(f) response (Entergy, 2016) regarding the flood event duration (FED) parameters for flood hazards not bounded by the CDB. The FED parameters for the flood-causing mechanisms not bounded by the CDB are summarized in Table 4.2-1.

The licensee did not provide FED parameters for LIP. The licensee developed FED parameters as part of the ANO MSA dated May 31, 2017 (Entergy, 2017b). The NRC will provide its assessment of the ANO MSA in a separate letter.

4.3 Associated Effects for Hazards Not Bounded by the CDB

The NRC staff reviewed information provided in Entergy's 50.54(f) response (Entergy, 2016) regarding associated effects (AE) parameters for flood hazards not bounded by the CDB. The AE parameters were not submitted as part of the FHRR and are noted as "not provided" in this table. The licensee is expected to develop AE parameters for LIP to conduct the MSA and focused evaluations as discussed in Appendix G to Nuclear Energy Institute (NEI)-12-06, Revision 2 (NEI, 2015a). The NRC staff notes that the licensee developed AEparameters as part of the ANO MSA dated May 31, 2017 (Entergy, 2017b). The NRC will provide its assessment of the ANO MSA in a separate letter.

4.4 Conclusion

Based upon the preceding analysis, the NRC staff confirms that the reevaluated flood hazard information discussed in Section 4 is appropriate input to the additional assessments of plant response as described in the 50.54(f) letter (NRC, 2012a), COMSECY-15-0019 (NRC, 2015), and the associated guidance.

As noted above, the licensee developed FED parameters and applicable flood AEs to conduct the MSA, as discussed in the NEI 12-06 (Revision 2), Appendix G (NEI, 2015a). The NRC staff will evaluate FED parameters and flood-related AE marked as "not provided" in Tables 4.2-1 and 4.3-1 during its review of the MSA and focused evaluations.

5.0 AUDIT REPORT

On November 14, 2016 (NRC, 2016e), the NRC staff issued an audit plan to support the staff's review of the ANO FHRR. As discussed in Section 3.0 of this document, the licensee made several calculation packages available for the NRC staff review. The NRC staff found that the information provided in the calculation packages expanded upon and clarified information provided in the ANO FHRR. The NRC staff concludes that a separate audit report is not necessary and that this document serves as the audit report described in the NRC staff's November 14, 2016, letter.

6.0 CONCLUSION

The NRC staff reviewed the information provided for the reevaluated flood-causing mechanisms for ANO, Units 1 and 2. Based on the review of the above available information provided in Entergy's 50.54(f) response (Entergy, 2016), the NRC staff concludes that the licensee conducted the hazard reevaluation using present-day methodologies and regulatory guidance used by the NRC staff in connection with ESP and COL reviews.

Based 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 NRC staff confirmed the licensee's conclusions that: (1) the reevaluated flood hazard results for LIP is not bounded by the CDB flood hazard; (2) additional assessments of plant response will be performed for LIP; and (3) the reevaluated flood- causing mechanism information is appropriate input to the additional assessments of plant response as described in the 50.54(f) letter and COMSECY-15-0019 (NRC, 2015a) and associated guidance. The NRC staff has no additional information needs at this time with respect to Entergy's 50.54(f) response.

6.0 REFERENCES

Notes: 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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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

SRP is the Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition (NRC, 2007)

JLD-ISG-2012-06 is the "Guidance for Performing a Tsunami, Surge, or Seiche Hazard Assessment" (NRC, 2013a)

JLD-ISG-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 and Associated Effects that May Exceed the Finished Floor Elevation (354.0 ft)[1]	Elevation, NGVD29
Local Intense Precipitation and Associated Drainage	
West of Diesel Oil Storage Tank	354.5 ft.
Between Warehouse and Reactor Building Unit 2	355.0 ft.
South of Turbine Building Units 2	355.1 ft.
South of Central Support Building	354.0 ft.
North of Central Support Building	357.7 ft.
North Train Bay Door	354.4 ft.
South Train Bay Door	354.4 ft.
Northeast of Turbine Building Unit 2	354.4 ft.
Transformer Yard	354.4 ft.
East of Turbine Building Unit 2	354.3 ft.
Northwest of Intake Structure	354.1 ft.
North of Intake Structure	354.2 ft.
North of Independent Spent Fuel Storage Installation	356.3 ft.
South of Independent Spent Fuel Storage Installation	355.6 ft.
Streams and Rivers	
Arkansas River PMF stillwater elevation	358 ft.
[[ ]]	[[ ]]
Arkansas River PMF with waves/runup (maximum all scenarios)	365.9 ft.

[1] Flood height and associated effects are as defined in JLD-ISG-2012-05 (NRC, 2012d)

Table 3.1-1. Current Design Basis Flood Hazards

Mechanism	Stillwater Elevation	Waves/Runup	Design Basis Hazard Elevation	Reference
Local Intense Precipitation	Not included in DB	Not included in DB	Not included in DB	FHRR Table 4-1
Streams and Rivers				
PMF on Arkansas River	358.0 ft. NGVD29	10.0 ft.	368.0 ft. NGVD29	FHRR Table 4-1
[[ ]]	[[ ]]	[[ ]]	[[ ]]	[[ ]]
Failure of Dams and Onsite Water Control/Storage Structures	Not included in DB	Not included in DB	Not included in DB	FHRR Table 4-1
Storm Surge	Not included in DB	Not included in DB	Not included in DB	FHRR Table 4-1
Seiche	Not included in DB	Not included in DB	Not included in DB	FHRR Table 4-1
Tsunami	Not included in DB	Not included in DB	Not included in DB	FHRR Table 4-1
Ice-Induced Flooding	Not included in DB	Not included in DB	Not included in DB	FHRR Table 4-1
Channel Migrations/Diversions	Not included in DB	Not included in DB	Not included in DB	FHRR Table 4-1

Table 4.1-1 Reevaluated Hazard Elevations for Flood-Causing Mechanisms Not Bounded by the CDB

Mechanism	Stillwater Elevation	Waves/Runup	Reevaluated Hazard Elevation	Reference
Local Intense Precipitation				
North Train Bay Door	354.4 ft. NGVD29	Minimal	354.4 ft. NGVD29	FHRR Table 4-2
South Train Bay Door	354.4 ft. NGVD29	Minimal	354.4 ft. NGVD29	FHRR Table 4-2
Between Warehouse and Reactor Building Unit 2	355.0 ft. NGVD29	Minimal	355.0 ft. NGVD29	FHRR Table 4-2
West of Maintenance Building	353.7 ft. NGVD29	Minimal	353.7 ft. NGVD29	FHRR Table 4-2
North of Turbine Building Unit 2	353.7 ft. NGVD29	Minimal	353.7 ft. NGVD29	FHRR Table 4-2
South of Turbine Building Unit 2	355.1 ft. NGVD29	Minimal	355.1 ft. NGVD29	FHRR Table 4-2
South of Central Support Building	354.0 ft. NGVD29	Minimal	354.0 ft. NGVD29	FHRR Table 4-2
North of Central Support Building	357.7 ft. NGVD29	Minimal	357.7 ft. NGVD29	FHRR Table 4-2
Northeast of Turbine Building Unit 2	354.4 ft. NGVD29	Minimal	354.4 ft. NGVD29	FHRR Table 4-2
Transformer Yard	354.4 ft. NGVD29	Minimal	354.4 ft. NGVD29	FHRR Table 4-2
East of Turbine Building Unit 1	354.3 ft. NGVD29	Minimal	354.3 ft. NGVD29	FHRR Table 4-2
Northwest of Intake Structure	354.1 ft. NGVD29	Minimal	354.1 ft. NGVD29	FHRR Table 4-2
North of Intake Structure	354.2 ft. NGVD29	Minimal	354.2 ft. NGVD29	FHRR Table 4-2
North of ISFSI	356.3 ft. NGVD29	Minimal	356.3 ft. NGVD29	FHRR Table 4-2
South of ISFSI	355.6 ft. NGVD29	Minimal	355.6 ft. NGVD29	FHRR Table 4-2
East of Cooling Tower	351.4 ft. NGVD29	Minimal	351.4 ft. NGVD29	FHRR Table 4-2
West of Warehouse	351.2 ft. NGVD29	Minimal	351.2 ft. NGVD29	FHRR Table 4-2
South of Warehouse	351.4 ft. NGVD29	Minimal	351.4 ft. NGVD29	FHRR Table 4-2
West of Diesel Oil Storage Tank	354.5 ft. NGVD29	Minimal	354.5 ft. NGVD29	FHRR Table 4-2
West of Engineering/Modification Building	352.2 ft. NGVD29	Minimal	352.2 ft. NGVD29	FHRR Table 4-2
Between Engineering/Modification Building and Reactor Building 1	352.7 ft NGVD29	Minimal	352.7 ft NGVD29	FHRR Table 4-2

East of Diesel Fuel Storage Vault	353.7 ft. NGVD29	Minimal	353.7 ft. NGVD29	FHRR Table 4-2

Note 1: Reevaluated hazard mechanisms bounded by the current design-basis (see Table 3.1-1) are not included in this table.
Note 2: Reported values are rounded to the nearest one-tenth of a foot.

Table 4.2-1. Flood Event Duration Parameters for Flood-Causing Mechanisms Not Bounded by the Plant's CDB

Mechanism	Time Available for Preparation for Flood Event	Duration of Inundation of Site	Time for Water to Recede from Site
Local Intense Precipitation	Not Provided*	Not Provided	Not Provided

*The licensee may use NEI 15-05 (NEI, 2015).

Note 1: Reevaluated hazard mechanisms bounded by the CDB (see Table 1) are not included in this table.

Table 4.3-1. Associated Effects Parameters not Directly Associated with Total Water Height for Flood-Causing Mechanisms not Bounded by the CDB

	Flooding Mechanism
Associated Effects Factor	**Local Intense Precipitation**
Hydrodynamic loading at plant grade	Not provided[1]
Debris loading at plant grade	Not provided
Sediment loading at plant grade	Not provided
Sediment deposition and erosion	Not provided
Concurrent conditions, including adverse weather	Not provided
Other pertinent factors (e.g., waterborne projectiles)	Not provided

[1] The NRC staff will evaluate associated effects parameters as part of future additional assessments.

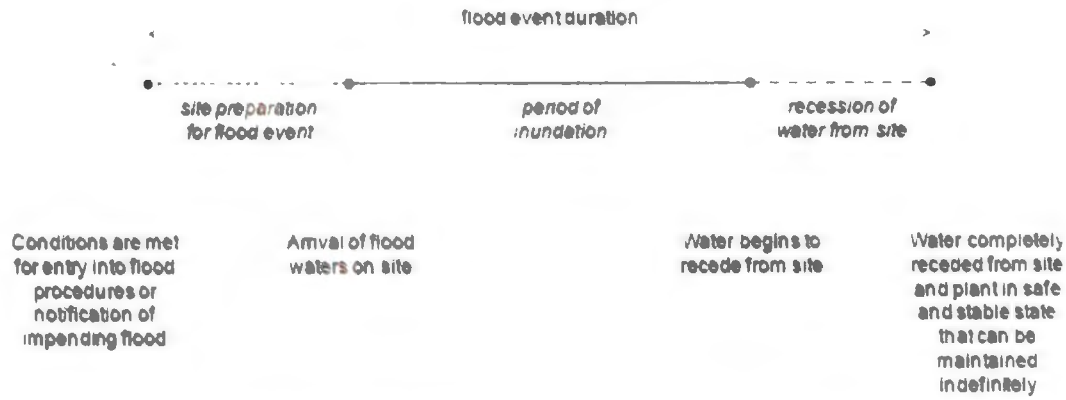

Figure 2.2-1. Flood Event Duration (NRC, 2012c)

Any illegible text or features in this figure are not pertinent to the technical purposes of this document

Figure 3.1-1. Site Location Map for ANO. (Derived from Entergy, 2016).
Note: Elevations in this figure are relative to NAVD88. The conversion factor from NGVD29 to NAVD88 to is 0.03 ft.

Figure 3.1-2 Map of Power Block Area (Derived from Entergy, 2015b).

ARKANSAS NUCLEAR ONE, UNITS 1 AND 2 - STAFF ASSESSMENT OF RESPONSE TO 10 CFR 50.54(f) INFORMATION REQUEST – FLOOD-CAUSING MECHANISM REEVALUATION DATED AUGUST 29, 2017

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