UNITED STATES
NUCLEAR REGULATORY COMMISSION
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January 24, 2018

Mr. David B. Hamilton
FirstEnergy Nuclear Operating
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SUBJECT: PERRY NUCLEAR POWER PLANT, UNIT 1 - STAFF ASSESSMENT AND SUMMARY REPORT FOR THE AUDIT OF THE RESPONSE TO 10 CFR 50.54(f) INFORMATION REQUEST – FLOOD-CAUSING MECHANISM REEVALUATION (CAC NO. MF6099; EPID L-2015-JLD-0004)

Dear Mr. Hamilton:

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 March 24, 2016 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML16084A871), FirstEnergy Nuclear Operating Company (FENOC, the licensee) responded with a revised response to this request for Perry Nuclear Power Plant, Unit 1 (Perry).

By letter dated June 8, 2015 (ADAMS Accession No. ML15153A145), the NRC notified FENOC of the staff's plan to perform a regulatory audit of Perry's supporting calculations of the Flood Hazard Reevaluation Report. The technical audit was performed consistent with NRC Office of Nuclear Reactor Regulation, Office Instruction LIC-111, "Regulatory Audits," dated December 29, 2008 (ADAMS Accession No. ML082900195).

By letter dated July 25, 2016 (ADAMS Accession No. ML16202A350), 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 July 25, 2016, letter and also summarizes and documents the results of the audit performed. As stated in the letter, the reevaluated flood hazard result for the following mechanisms were not bounded by the Perry current design basis (CDB) flood hazard: local intense precipitation, streams and rivers, and storm surge. The NRC staff notes that for the flood-causing mechanisms that are not bounded by the CDB, the licensee has submitted a mitigation strategies assessment (MSA) dated July 24, 2017 (ADAMS Accession No. ML17205A336), which is currently being reviewed by the NRC. In addition, FENOC is expected to submit a focused evaluation consistent with the process described by NRC letter dated September 1, 2015, "Coordination of Requests for Information Regarding Flooding Hazard Reevaluations and Mitigating Strategies for Beyond-Design-Basis External Events," (ADAMS Accession No. ML15174A257).

The NRC staff will provide its assessment of the Perry focused evaluation in a separate letter. This closes out the NRC's efforts associated with CAC No. MF6099.

The contents of this letter have been discussed with Mr. Phil Lashley of your staff. If you have any questions, please contact me at (301) 415-3809 or by e-mail at Juan.Uribe@nrc.gov.

Sincerely,

Juan Uribe, Project Manager
Beyond-Design-Basis Management Branch
Division of Licensing Projects
Office of Nuclear Reactor Regulation

Docket No. 50-440

Enclosures:
1. Staff Assessment of Flood Hazard Reevaluation Report
2. Audit Summary Report

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STAFF ASSESSMENT AND AUDIT REPORT BY THE OFFICE OF NUCLEAR REACTOR REGULATION RELATED TO THE FLOODING HAZARD REEVALUATION REPORT NEAR-TERM TASK FORCE RECOMMENDATION 2.1 FOR PERRY NUCLEAR POWER PLANT, UNIT 1

DOCKET NO. 50-440

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

By letter dated March 10, 2015, FENOC, 2015), First Energy Nuclear Operating Company (FENOC, the licensee) provided the FHRR for Perry Nuclear Power Plant, Unit 1 (Perry). The licensee revised the FHRR by letter dated March 24, 2016 (FENOC, 2016). In order to perform its review, the NRC staff conducted a site audit with the licensee, as summarized in the Audit Summary Report. The results of that audit are summarized in Enclosure 2 of this document.

On July 25, 2016, the NRC issued an interim staff response (ISR) letter to the licensee (NRC, 2016c). 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 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 local intense precipitation (LIP), streams and rivers, and storm surge flood-causing mechanisms 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, 2015a), Japan Lessons-Learned Division (JLD) Interim Staff Guidance (ISG) JLD-ISG-2012-01, Revision 1 (NRC, 2016b) 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. Additionally, for the streams and rivers and storm surge flood-causing mechanisms, the NRC staff anticipates that the licensee will submit either (a) a revised integrated assessment or (b) a focused evaluation (FE) confirming the capability of existing flood protection or implementing new flood protection consistent with the process outlined in COMSECY-15-0019 (NRC, 2015b) and JLD-ISG-2016-01, Revision 0 (NRC, 2016c).

Additionally, for any reevaluated flood hazards that are not bounded by the plant's CDB hazard, the licensee is expected to develop flood event duration (FED) parameters and associated effects (AE) parameters. These parameters will be used to conduct the mitigating strategies assessment (MSA), and the FE or revised integrated assessment. By letter dated July 24, 2017, the licensee submitted its MSA, which included several revisions to hazards described in the FHRRs Rev. 0 and Rev. 1. Consequently, the MSA referenced Rev. 2 of the Perry FHRR and included additional FED and AE parameters not provided in the previous FHRR (FENOC, 2017). The revisions to the hazards and parameters, along with the NRC staff's review and conclusions, are documented in a separate staff assessment corresponding to the MSA review.

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 for 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 reports, 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 10 CFR 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 the 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 an analysis (based on calculation, experiments, or both) of the effects of a postulated accident for which an SSC must meet its functional goals.

Section 54.3 of 10 CFR defines the “current licensing basis” (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 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 to Enclosure 2 of the 50.54(f) letter discusses flood-causing mechanisms for the licensee to address in the FHRR (NRC, 2012a). Table 2.2-1 lists the flood-causing mechanisms that the licensee should consider, and 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, 2012d), 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 Effects 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 synonymous. Even if some or all of the 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 any of the 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 CDB (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 all flood-causing mechanisms at the site, licensees are not required to perform an integrated assessment. COMSECY-15-0019 (NRC, 2015a) 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 LIP hazards exceeding their CDB flood will not be required to complete an integrated assessment, but instead will 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, 2015a and NRC, 2016b).

3.0 TECHNICAL EVALUATION

The NRC staff reviewed the information provided for the flood hazard reevaluations of the Perry site (FENOC; 2015a, 2016). The licensee conducted the hazard reevaluation using present-day methodologies and a 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 Perry FHRR, the licensee made calculation packages available to the NRC staff via an electronic reading room. The NRC staff did not rely directly on these calculation packages in its review; they were found only to expand upon and clarify the information provided in the initial and revised Perry FHRR, and so those calculation packages were not docketed or cited.

3.1 Site Information

The 50.54(f) letter includes the SSCs important to safety in the scope of the hazard reevaluation. The licensee included pertinent data concerning these SSCs in the initial Perry FHRR (FENOC, 2015a) and a subsequent revision (FENOC, 2016). The NRC staff reviewed and summarized this information in the sections below.

3.1.1 Detailed Site Information

The Perry FHRRs described the site specific information related to the flood hazard reevaluation. The Perry site is located on the south bank of Lake Erie in Lake County, Ohio, about 7 miles (mi) northeast of the town of Painesville, Ohio.

The elevations in this staff assessment are given with respect to the National Geodetic Vertical Datum of 1929 (NGVD29). The site grade ranges from 617 to 620 feet (ft.) NGVD29 for most of the protected area; and, the plant grade of building floors and design-basis of features related to plant safety are located at elevation 620.5 ft. NGVD29. Table 3.1-1 summarizes the controlling reevaluated flood-causing mechanisms the licensee computed to be higher than the powerblock elevation. The FHRR states that the site is on an area above the Lake Erie shoreline, situated on a bluff that provides protection from the maximum lake water level.

3.1.2 Design-Basis Flood Hazards

The CDB flood levels are summarized by flood-causing mechanism in Table 3.1-2 of this staff assessment. The licensee presented design-basis flood elevation information in Table 5 of its initial FHRR (FENOC, 2015a). The licensee stated that the flooding mechanisms that have a CDB are LIP, streams and rivers, and storm surge. The licensee reported that all other mechanisms could not inundate the plant site.

3.1.3 Flood-Related Changes to the Licensing Basis

The licensee stated in the revised Perry FHRR (FENOC, 2016) that there are no flood related changes to the CLB; however, physical changes have been made to the site (NRC, 2017a).

3.1.4 Changes to the Watershed and Local Area

The licensee stated in the Perry FHRR (FENOC, 2015a; 2016) that there have been a number of structures added and removed, and security barrier upgrades have been added since the initial plant license. More recent changes include modifications of topographical features that result in greater conveyance of water in streams adjacent to the site. This results in the site not being impacted by flooding from the adjacent Major Stream west of the site, or by the Minor Stream east of the site. These modifications also include channelization of the Diversion Stream on the northeast boundary of the site; a railroad bridge southwest of the site was removed, and a secondary access road was raised to protect the site (FENOC, 2016). On June 29, 2017, the NRC and FENOC held a public meeting regarding these changes (NRC, 2017a).

3.1.5 Current Licensing Basis Flood Protection and Pertinent Flood Mitigation Features

The licensee stated in the initial Perry FHRR (FENOC, 2015a) that the site CDB flood was based on LIP occurring on the site with a maximum water height reaching building floor levels at an elevation of 620.5 ft. NGVD29. In FHRR Section 2.3, the licensee described the flood mitigation features for the safety-related buildings at the Perry site. The NRC staff reviewed the information provided in the Perry FHRR and determined that sufficient information was provided to be responsive to Enclosure 2 of the 50.54(f) letter.

3.1.6 Additional Review Details to Assess the Flood Hazard

As part of the technical audit process described above, the licensee provided electronic versions of the input and output files used for numerical models related to the analysis of LIP in the initial and revised Perry FHRRs (FENOC, 2015a; 2016). As previously stated, the NRC staff did not rely directly on these input/output files and calculation packages in its review; they were found only to expand upon and clarify the information provided in the initial and revised Perry FHRR, and so those calculation packages were not docketed or cited. The results of the audit report are summarized in Enclosure 2 of this document.

3.1.7 Results of Plant Walkdown Activities

The 50.54(f) letter 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 (FENOC, 2012), FENOC provided a flooding walkdown report in response to Enclosure 4 of the 50.54 (f) letter Required Response Item 2, for Perry. On June 30, 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 Local Intense Precipitation

The licensee reported in its revised FHRR, that the reevaluated flood hazard for LIP and associated site drainage is based on stillwater-surface elevations at the safety-related structures that range from 619.9 ft. to 621.3 ft. NGVD29 at the Perry Power Block area. The locations of the Power Block and other key areas are presented in Figure 3.2-1.

This flood-causing mechanism is discussed in the licensee's CDB. The CDB probable maximum flood (PMF) elevation for LIP and associated site drainage is based on a stillwater-surface elevation of 620.5 ft. NGVD29.

During its review of the LIP for Perry, the NRC staff identified additional information needed from the licensee to supplement and clarify existing information in the FHRR. The licensee addressed the information needs during the site audit conducted on June 21, 2016. The audit summary documenting the NRC actions and conclusions is discussed in Enclosure 2 of this document and the appropriate sections below.

3.2.1 Probable Maximum Precipitation

The licensee considered the 6-hour (h) 1-mi^2 site specific probable maximum precipitation (ssPMP) for the LIP analysis. The licensee evaluated five temporal distributions (front, one-third, central, two-third, and end-loaded) and found that the end-loaded distribution results in the maximum flow depth. To verify the licensee's ssPMP, the NRC staff requested Oak Ridge National Laboratory (ORNL) to review the Perry ssPMP. As an efficiency step, ORNL performed an independent sensitivity study and calculated an adjusted ssPMP for the Perry site. The adjusted ssPMP implemented changes to the storm representative dew points and the total adjustment factor of controlling storms. The adjusted ssPMP resulted in larger precipitation depths than the licensee's ssPMP for all temporal durations (see Table 3.2-1). The NRC staff performed a sensitivity analysis by applying the licensee's LIP model (see Section 3.2.2) with the two different ssPMP results. Variations in water depths near key structures were not significant (within 0.3 ft). Therefore, the NRC staff concludes that the licensee's LIP analysis using the licensee's ssPMP is reasonable for the purposes of FENOC's 50.54(f) response.

3.2.2 LIP Model Construction and Parameters

The licensee performed the LIP analysis using the two-dimensional hydrodynamic FLO-2D model, build version 14.08.09 (FLO-2D, n.d.). In the FLO-2D model, the licensee assumed that: a) the infiltration loss was zero, and b) the peak water level of the Major Stream is coincident with the duration of the LIP event. The NRC staff reviewed these assumptions and concludes that they are conservative and consistent with NUREG/CR-7046 (NRC, 2011e) and ANSI/ANS 2.8 (ANSI, 1992).

The FLO-2D model was constructed using the ground surface topography, a digital terrain model (DTM), referenced to a vertical datum (ft. North American Vertical Datum of 1988 (NAVD88)). The FLO-2D model domain covers the entire site, including the power block area, Service/Emergency Service Water Pumphouse north of the power block area, Circulating Water Pumphouse (Unit 1 and Unit 2) east of the power block area and parking lots (Figure 3.2-1). A refined grid cell size of 10 ft. by 10 ft. was used in the model to incorporate detailed site structures. The NRC staff reviewed the grid size and the model domain and confirmed that the selected grid size is reasonable and the model domain covers the entire site.

The licensee considered a berm between the diversion channel and the Minor Stream as the eastern boundary, and Secondary Access Road and plant access road as the southern boundary of the model domain (Figure 3.2-2). The diversion channel and the berm were constructed, and the access roads were modified through site modifications that were implemented in 2015 (FENOC, 2016). As stated in the FHRR, the Secondary Access Road was raised to block the flow from the depression area to the Perry site, and the berm was constructed to prevent flooding due to the PMF in the Diversion Channel. The NRC staff verified through review of the licensee Diversion Channel Hydrologic Engineering Center - River Analysis System (HEC-RAS) model output that the PMF at the diversion channel does not exceed the berm elevation or the Secondary Access Road controlling elevation.

The licensee used Light Detection and Ranging (LiDAR) data and 2012 survey data in NAVD88 as the FLO-2D model inputs and indicated that the 2012 survey data has an uncertainty of 0.21 ft. (FENOC, 2015a). To address the potential error due to this uncertainty, the licensee added 0.21 ft. to the results of the FLO-2D model while converting the elevations from NAVD88 to NGVD29. The NRC staff concludes that this approach is conservative.

The licensee determined the land cover based on visual assessment of aerial photography and then assigned the Manning's roughness coefficient (*n)* for each grid cell corresponding to the land-cover-type ranges in the FLO-2D Reference Manual (FLO-2D, n.d.). The NRC staff reviewed the assigned *n* values and confirmed that the licensee's values are reasonable for the majority of the land cover types. For the tree areas, the NRC staff noticed that the assigned *n* value was from the low end of the range. However, through an independent staff-conducted sensitivity analysis, the NRC staff verified that the model results are not sensitive to the *n* value in tree areas.

In the FLO-2D model, the licensee added a levee system around the perimeter of the buildings to represent the buildings that have rooftop parapets as part of building structures. Although the use of levees around the building perimeters allows water storage on the rooftops, the NRC staff removed the levees from the rooftop of the buildings in the sensitivity analysis and noted this removal had minimal effect on WSEs in the plant area. During the audit, the licensee confirmed that the buildings at Perry are structurally able to hold 1 ft of water on the rooftop and that levees were not added to the buildings that do not have a parapet wall in the model. The NRC staff concludes that the licensee's approach to integrate the levee system into the building grid elements in the model is reasonable.

The licensee included flow routing in the analysis by including installed storm drains, underdrains, and roof drain systems in the Environmental Protection Agency (EPA) Storm Water Management Model (SWMM) (USEPA, 2010), which was integrated with the site FLO-2D model. The licensee justified use of this model by describing the ground surface of the Perry site is mostly covered with asphalt paving and concrete, and debris is not expected. Therefore, completely blocking the drainage system would overestimate the WSEs. As a conservative measure, the licensee incorporated a partial reduction of the drainage system into the model. To evaluate the impact level of a potentially non-functional drainage systems during the LIP event, the NRC staff independently ran the FLO-2D model without the SWMM component (i.e., complete blockage of the drainage system). The results showed a limited impact on WSE at important-to-safety locations as only four additional locations would have maximum WSEs exceeding the threshold door elevation beyond the group of 63 locations determined using the licensee's model. Among the four locations, the increase in the maximum WSEs was within the range of 0.01 to 0.56 ft. Considering the licensee's other conservative assumptions in the model (zero infiltration, inclusion of the drainage area of Minor Stream, and peak flow in the

Major Stream as a boundary condition), the NRC staff agree that the licensee's models are appropriate for use in the FHRR.

3.2.3 LIP Model Results

The reevaluated maximum WSEs in the licensee's LIP analysis using the FLO-2D model range from 619.9 ft to 621.3 ft NGVD29 in the Power Block area. These WSEs are not bounded by the CDB. The licensee reported the flood hazard results at 83 locations, and the results showed that the maximum WSEs at 63 out of 83 locations exceeded the threshold door elevations; 57 in the power block area, 4 at the Service/Emergency Service Water Pumphouse, and 2 at the Circulating Water Pumphouse for Unit 2, as shown on Figure 3.2-1. The Circulating Water Pumphouse for Unit 2 was abandoned and flooding at the exterior of this building was not considered.

3.2.4 NRC Staff Conclusion

The NRC staff reviewed the LIP analysis and concluded that the licensee's approach is consistent with present-day methodologies and regulatory guidance.

The NRC staff confirms the licensee's conclusion that the reevaluated flood hazard for LIP and associated site drainage is not bounded by the CDB. Therefore, the NRC staff expects the licensee will submit a focused evaluation for LIP.

3.3 Streams and Rivers

The licensee reported in the revised FHRR that the reevaluated flood hazard for streams and rivers is based on stillwater-surface elevations of 628.5 ft NGVD29 at the Major Stream at the Rail Line Bridge, and 619.7 ft NGVD29 at the Minor Stream adjacent to the Unit 2 Turbine building. Figure 3.3-1 shows the layout of the Perry site and the streams and rivers where flooding was evaluated.

This flood-causing mechanism is discussed in the licensee's CDB. The CDB probable maximum flood elevation for streams and rivers is based on the stillwater-surface elevation of 624.0 ft NGVD29 at the Major Stream and 619.5 ft NGVD29 at the Minor Stream.

The NRC staff requested information needs from the licensee to supplement the FHRR. The licensee provided the information needs through a site audit conducted on June 21, 2016. As previously stated, the audit summary is included in Enclosure 2 and discussed in the appropriate sections below.

3.3.1 Probable Maximum Precipitation

The licensee developed two types of probable maximum precipitation (PMP) depths: ssPMP and the PMP based on HMR-33 (National Oceanic and Atmospheric Administration (NOAA), 1956) and HMR-52 (NOAA, 1982) (referred to here as "HMR PMP") for Perry. The licensee estimated both all-season and cool-season PMP, and found that the all-season PMP is the governing PMP for PMF analysis. As presented in FHRR Revision 1 (FENOC, 2016), the licensee applied a 72-h ssPMP for the relatively-larger Major Stream basin and the associated depression area basin east of Major Stream and a 48-h HMR PMP for the smaller Minor Stream basin and Diversion (Re-aligned) Channel basin. The adjusted ssPMP discussed in Section 3.2.1 was also applied as part of this hazard analysis, and the resulting PMP values are presented in Table 3.2-1. The NRC staff performed a sensitivity analysis by comparing the resulting water surface elevations (WSEs) generated using this adjusted ssPMP and the licensee's ssPMP. The results are discussed in Section 3.3.3 of this staff assessment.

The licensee evaluated five temporal distributions (front-, one-third-, center-, two-third-, and end-loading) and found that the PMP with one-third, center, and two-third-loaded temporal distributions produced the maximum and identical results for peak flows, WSEs, and water depths in the streams at the Perry site. The licensee selected the center-loaded temporal distribution PMP in all models for the results presented in the FHRR. The NRC staff agrees that this approach is reasonable. The NRC staff also examined the PMP values inputs to all hydrologic models and found them consistent with those reported in the FHRR (FENOC, 2016).

3.3.2 Model Construction

The licensee performed a flood analysis using the U.S. Army Corps of Engineers (USACE) HEC- Hydrologic Modeling System (HEC-HMS) (USACE, 2010b) and HEC-RAS (USACE, 2010a) models. As discussed in FHRR Rev. 1, the licensee updated the HEC-HMS and HEC-RAS models according to the site modifications at Perry in 2015. The main modifications reported in the revised FHRR include:

- Modification of Major Stream floodplain including (1) removal of the abandoned railroad embankment near the Major Stream allowing greater conveyance between the eastern and western overbanks of the Major Stream, which discharges northward to Lake Erie directly; and (2) raising the Secondary Access Road to prevent local inflow to the plant from the area between the railroad and the Secondary Access Road.

- Addition of a realigned Diversion Channel that collects runoff from about 84 percent of the original Minor Stream drainage area from the east of the Minor Stream, diverts stream flow out of the Minor Stream at the upstream location, and guides the flow discharge directly to Lake Erie. A berm was also added between the Diversion Channel and the Minor Stream/Power Block area to provide a barrier preventing flooding flow from the diversion channel.

The licensee evaluated the PMFs and WSEs using HEC-HMS and HEC-RAS models for the Major Stream, Minor Stream, a depression area east of Major Stream and southwest of the Secondary Access Road, and the Diversion Channel (Figure 3.3-1) (FENOC, 2016). The NRC staff determined that the licensee's modeling approach is appropriate, and is consistent with present-day hydrologic and hydraulic modeling practices.

The following key assumptions were made in the models: a) the runoff infiltration loss was assumed to be zero, and b) Minor Stream Lockwood Road crossing and culvert at the outfall of the Diversion channel are assumed to be completely blocked in the models. The NRC staff reviewed these assumptions and concludes that they are conservative and consistent with guidance NUREG/CR-7046 (NRC, 2011e) and ANSI/ANS 2.8 (ANSI 1992).

The licensee determined the land cover based on a visual assessment of aerial photography and then assigned a Manning's n coefficient to specific land cover types based on suggested ranges described in the HEC-RAS Hydraulic Reference Manual (USACE, 2010b). The NRC staff reviewed the assigned Manning's n values and noticed that for some of the land cover types the assigned values were not from the high end of the range.

Therefore, a sensitivity analysis was performed by the staff, changing the Manning's *n* values for some land cover types. The results of staff sensitivity analysis are discussed in Section 3.3.3 of this staff assessment.

To simulate the PMF at the Perry site, the licensee constructed four separate hydrologic models in HEC-HMS: 1) Major Stream, 2) a depression area south of the plant area which is enclosed by the rail road to the north, Secondary Access Road to the east and northeast, and Major Stream to the west (Figure 3.3.-1), 3) Minor Stream, and 4) Diversion Channel. Models 1, 3 and 4 were used to quantify the PMFs, which served as inputs to the hydraulic models in HEC-RAS. Model 2 was a stand-alone model, in which sub-basins were treated as reservoirs and maximum WSEs were determined using the storage-elevation relationship without using the HEC-RAS model.

To translate the rainfall (or PMP) into runoff (or PMF) in the hydrological models, the licensee derived a unit hydrograph using the Natural Resources Conservation Service (NRCS) transform parameters (USDA, 2007). The licensee adjusted the derived unit hydrograph by increasing the discharge by one-fifth and decreasing the time-to-peak by one third as per recommendations in NUREG/CR-7046 to account for the effects of nonlinear basin response to the PMF. The NRC staff confirmed that the unit hydrograph was derived using the methodology based on current hydrological practice.

Three separate hydraulic models were constructed for the Major Stream, Minor Stream, and Diversion Channel by applying HEC-RAS. The PMFs derived by the hydrologic models were used as inputs to the upstream boundary of the HEC-RAS models. The peak lake water level of 574.22 ft. NAVD88 that was converted from the observed data in the International Great lakes Datum of 1985 and was used in the models as the most downstream boundaries at Lake Erie. The NRC staff reviewed the models, including the boundary conditions where output from one or more hydrologic model was transferred to the hydraulic model(s), and conclude the licensee's approach is reasonable.

3.3.3 Models Results

The model results indicated that the maximum WSE is 628.5 ft. NGVD29 in the Major Stream at the rail line bridge, and 618.7 ft. to 619.7 ft. NGVD29 in the Minor Stream adjacent to the Unit 1 Turbine building and Unit 2 Turbine building. The reevaluated maximum WSEs based on the model results are not bounded by the CDB for the Major Stream (624.0 ft. NGVD29) and Minor Stream (619.5 ft. NGVD29). However, the reevaluated maximum WSEs in the Major Stream are below the stream overbank and will not result in any flooding to the Minor Stream or inundate the Perry Power Block area. The maximum WSEs in the Minor Stream are also below the plant grade elevation of building floors (620.5 ft. NGVD29) and are not expected to inundate the Power Block area.

For the Diversion Channel drainage basin, the computed maximum WSE along the channel is 629.2 ft. NGVD29 at the upstream area. There is no CDB for the Diversion Channel drainage basin as the channel was constructed through the site modifications implemented in 2015 (FENOC, 2016). The maximum WSE calculated for the Diversion Channel (629.2 ft. NGVD29) is lower than the berm crest elevation (630.9 ft. NGVD29) and the PMF in the Diversion Channel would not overtop the berm and hence could not inundate the Powerblock area.

For the depression area south of the plant, the estimated maximum WSE is 631.3 ft. NGVD29 at the north side and 631.4 ft. NGVD at the east side. The licensee stated that in order to keep flood waters contained within the depression area and prevent them from inundating the Perry site during the PMF event, the Secondary Access Road was raised to an elevation of 631.4 ft. NAVD29 or higher during the site modification (FENOC, 2016).

The licensee reported in the Perry FHRR that wind wave activity on the Major Stream and Diversion Stream are not consequential because neither the Major Stream nor the Diversion Stream is directly adjacent to safety-related structures. The licensee also reported that because the Minor Stream remains within its banks, wind wave effects at the power block will not develop.

The NRC staff performed a sensitivity analysis by applying the licensee's HEC-RAS model with increasing Manning's n values to the upper-recommended range in the channel or over the overbank area or both for the Major Stream, Minor Stream, and Diversion Channel. The model results showed increases in maximum WSEs for both streams and the Diversional Channel. However, the magnitude of increased WSEs does not change the licensee's conclusions that the maximum WSEs in streams will not exceed the stream overbank (Major Stream), plant grade (adjacent to the Minor Stream), or the berm crest elevation (Diversion Channel) and the Power Block area will not be inundated.

The NRC staff also performed a sensitivity analysis by applying the adjusted ssPMP for the Major Stream and a depression area east of the Major Stream. The HEC-HMS and HEC-RAS models results showed overflow from the Major Stream (Figure 3.3-1) and increase in WSE in the depression area. However, when realistic runoff loss via infiltration was considered in the analysis, the PMF and WSEs matched the licensee's results. Therefore, NRC staff finds that the licensee's results are reasonable, and agree that no overflow is expected to occur from the Major Stream.

3.3.4 NRC Staff Conclusion

The NRC staff reviewed the analysis related to streams and rivers and concluded that the licensee's approach is consistent with present-day methodologies and regulatory guidance (NUREG/CR-7046, NRC 2011e) for flooding. The NRC staff also confirmed the licensee's conclusion that the reevaluated hazard from streams and rivers is not bounded by the CDB flood hazard. Therefore, the NRC staff expects that the licensee will submit either a focused evaluation or revised integrated assessment for streams and rivers.

3.4 Failure of Dams and Onsite Water Control/Storage Structures

The licensee reported in the Perry FHRR that the reevaluated flood hazard for failure of dams and onsite water control or storage structures is not applicable to the Perry site (FENOC; 2015a, 2016). This flood-causing mechanism is not discussed in the licensee's CDB.

The NRC staff reviewed the USACE National Inventory of Dams database and determined that there were no dams located in the watershed that could contribute to flooding hazards at the Perry site (USACE, 2017b). Additionally, the NRC staff reviewed the FHRR and determined that there were no onsite water control or storage structures that would contribute to flooding on the Perry site (FENOC; 2015a, 2016).

In summary, the NRC staff confirmed the licensee's conclusion that the reevaluated hazard for flooding due to the failure of dams and onsite water control or storage structures could not inundate the Perry site. Therefore, the NRC staff determined that flooding from dam failure does not need to be further analyzed.

3.5 Storm Surge

The licensee reported in its FHRR, that the reevaluated flood hazard for storm surge is based on a stillwater-surface elevation of 582.8 ft. NGVD29 and 609.5 ft. NGVD29 when considering wind waves and runup results.

This flood-causing mechanism is discussed in the licensee's CDB. The CDB PMF elevation for storm surge is based on a stillwater-surface elevation of 580.5 ft. NGVD29. Including wind waves and runup results in an elevation of 607.9 ft. NGVD29. The licensee used the Delft3D-FLOW (Deltares, 2014a) and Delft3D-WAVE (Deltares, 2014b) software in their reevaluation of storm surge and associated wave effects. The licensee described the development of the probable maximum wind storm parameters, the bathymetric information used to configure the model, model calibration and validation, and the sensitivity of the model to key uncertainty parameters.

The NRC staff reviewed the NOAA databases cited by the licensee, including the climatology of Lake Erie, and confirmed that the controlling storm for PMSS calculations is an extra-tropical storm. The NRC staff independently ran the NOAA Storm Surge Planning Program (SSPP) (Great Lakes Storm Surge Planning Program; Schwab and Lynn, 1987) model using the same antecedent water level and a sustained wind speed of 100 mph consistent with ANSI/ANS guidance (ANSI/ANS, 1992). The NRC staff performed a sensitivity study by varying the wind direction in 10 degree increments between 10 and 360 degrees to determine the wind direction that produced the greatest surge elevation at the Perry site. The NRC staff's results produced a maximum still water level that compared well with the licensee's stillwater elevation.

The NRC staff confirmed the licensee's conclusion that the reevaluated hazard from flooding from storm surge is not bounded by the CDB flood hazard. Therefore, in accordance with the process described in COMSECY-15-0019 and by NRC letter dated September 1, 2015, "Coordination of Requests for Information Regarding Flooding Hazard Reevaluations and Mitigating Strategies for Beyond-Design-Basis External Events," (ADAMS Accession No. ML15174A257), the NRC staff expects that FENOC will submit a focused evaluation confirming the capability of existing flood protection at the Perry site.

3.6 Seiche

The licensee reported in its FHRR that the reevaluated hazard for seiche does not inundate the plant site, but did not report a PMF elevation. This flood-causing mechanism is not discussed in the licensee's CDB.

The licensee stated that the water level rise due to seiche is less than the calculated surge height. Additionally, the licensee stated the natural period of oscillation for Lake Erie is 11 to 15 hours which is longer than the peak spectral period of the storm surge waves. Consequently, the licensee concluded resonance would not produce a flooding hazard at the Perry site during the Probable Maximum Wind Storm (PMWS) occurrence.

The NRC staff performed independent calculations using Merian's Formula (USACE, 2008) to compute seiche in Lake Erie. The NRC staff estimated the primary natural period of oscillation using an average depth of Lake Erie of 58 ft. length of 241 mi and maximum width of 57 mi based on data contained reported by FENOC (FENOC, 2015b). The NRC staff's independent calculations yielded oscillation periods in the longitudinal (east-west) and lateral (north-south) directions of 16.4 hours and 3.9 hours, respectively. The NRC staff agrees with the licensee's conclusion that resonance is not a concern at the site during or subsequent to a PMWS occurrence.

The NRC staff reviewed the results of the water level spectral analysis done for Lake Erie (Platzman and Rao, 1964), which stated that the primary period of free oscillation in Lake Erie was about 14 hours. The NRC staff examined the USACE Wave Information Studies wind-wave summaries for four Lake Erie locations offshore (USACE Lake Erie Stations 95054, 95055, 95056, 95057) with depths of about 20 m below mean sea level; the wave periods for the storm events ranged from 8 to 10 seconds (USACE, n.d.). Based on this information, the NRC staff concludes that this oscillation period is greater than that associated with wind waves on Lake Erie, and therefore wind waves could not induce a seiche event.

The NRC staff confirmed the licensee's conclusion that the reevaluated hazard for flooding from seiche is bounded by the reevaluated PMSS flood hazard. Therefore, the NRC staff determined that flooding from seiche does not need to be further analyzed.

3.7 Tsunami

The licensee reported in its FHRR that the reevaluated hazard for tsunami does not inundate the plant site, but did not report a PMF elevation. This flood-causing mechanism is described as not applicable in the licensee's CDB.

The licensee used the HHA approach described in NUREG/CR-6966 (NRC, 2009) for the tsunami hazard assessment which included: (1) performing a regional survey to determine if the site region is subject to tsunamis; (2) assessing the mechanisms likely to cause a tsunami; and (3) performing a site screening to determine the potential tsunami effects to the Perry site. Based on the history of the area, the licensee stated that local seismic disturbances result in minor excitations in Lake Erie. In addition, the licensee stated that Lake Erie's submarine sediments lack sufficient volume and potential for rapid collapse to displace a water volume that would create a tsunami. The licensee also stated that historical earthquakes in the region were of insufficient magnitude to be conducive for the development of a tsunami at the Perry site. The licensee also noted that the recorded historical events were only minor disturbances or seiches and no actual tsunamis are evident near the Perry site. Therefore, the licensee concluded that there are no potential tsunamis or tsunami-like waves which could affect safety-related structures or components at the Perry site.

To verify licensee's conclusion, the NRC staff searched the National Geophysical Data Center (NGDC) (NGDC, 2014) tsunami database and found two historical events: one in the northern end of Lake Erie and the other near the Detroit River. The NRC staff's search spanned the entirety of the time period covered by the database and within the spatial bounds of 40 degrees to 44 degrees north, and 85 degrees to 77 degrees west and confirmed these events. The NRC staff found a maximum water change in height along the Canadian shore of Lake Erie of about 9 ft. (1823 event) observed at the northeast end of Lake Erie (NGDC, n.d.); no other observations for this event were reported. Based on the 100-year maximum WSE of Lake Erie, the magnitude of the historical event and the Perry site's nominal finished floor elevation, the NRC staff agrees that the licensee's conclusion for the Perry site was reasonable.

The NRC staff reviewed the licensee's results and agrees that historical records do not support any evidence of significant tsunami at or near the Perry site. The NRC staff confirmed the licensee's conclusion that the reevaluated hazard for flooding from tsunami could not inundate the site. Therefore, the NRC staff determined that flooding from tsunami does not need to be further analyzed.

3.8 Ice-Induced Flooding

The licensee reported in the Perry FHRR that the reevaluated hazard for ice-induced flooding does not inundate the plant site and is bounded by flooding due to the streams and rivers PMF flood hazard. This flood-causing mechanism is discussed in the licensee's CDB and is screened-out as not plausible.

The licensee used the USACE ice jam database to locate the maximum height ice jam in the vicinity of the site. The NRC staff confirmed that none of the immediately adjacent unnamed streams (i.e., Major Stream, Minor Stream, and Diversion Stream) had a history of ice jams, and that within the adjacent watersheds of Grand River and Ashtabula River the maximum historical ice jam was 18 ft. (USACE, 2017a). The NRC staff confirmed through examination of topography and models provided by the licensee that the only significant transposing of the historical ice jam to a different location would be on the Major Stream, and that all road crossings and culvert locations have clear passage that exceed the height of the transposed ice jam.

The NRC staff confirmed that the licensee's reevaluation of the hazard from ice-induced flooding used present-day methodologies and regulatory guidance. The NRC staff confirmed the licensee's conclusion that the reevaluated hazard for ice-induced flooding of the site is bounded by the streams and rivers flood hazard. Therefore, the NRC staff determined that ice-induced flooding does not need to be further analyzed.

3.9 Channel Migrations or Diversions

The licensee reported in the Perry FHRR that the reevaluated hazard for channel migrations or diversions does not inundate the plant site. This flood-causing mechanism is not discussed in the licensee's CDB.

The licensee stated in the Perry FHRR that historical records and hydrogeomorphological data were used to determine whether adjacent streams had a historical tendency to migrate towards the site (NRC, 2011e; FENOC, 2016). Through examination of surficial geology and topography, the licensee screened out channel migration or diversion as a plausible flood-causing mechanism for the Perry site. The NRC staff evaluated the potential for flooding resulting from channel migrations and diversions using the licensee-provided site layout and Google maps.

The NRC staff confirmed the licensee's conclusion that the channel migrations or diversions flood-causing mechanism could not inundate the Perry site. Therefore, the NRC staff also concludes that channel migration or diversion flooding does not need to be further analyzed.

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's review of the licensee's flood hazard water height results. Table 4.1-1 contains the maximum flood height results, including waves and run-up, for flood mechanisms not bounded by the CDB. The NRC staff agrees with the licensee's conclusion that the LIP, streams and rivers, and storm surge flood hazard mechanisms are not bounded by the CDB. Consistent with the process and guidance discussed in COMSECY-15-0019 (NRC, 2015a) and JLD-ISG-2016-01, Revision 0 (NRC, 2016c), the NRC staff anticipates the licensee will submit a focused evaluation for LIP and either a focused evaluation or a revised integrated assessment for streams and rivers and storm surge.

4.2 Flood Event Duration for Hazards Not Bounded by the CDB

The NRC staff reviewed information provided in FENOC's 50.54(f) response (FENOC, 2015b, 2015c, and 2016b) regarding the FED parameters needed to perform the additional assessment(s) of the plant response 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.

For the LIP flood-causing mechanism, the plant response to a LIP flood event does not credit warning time because the entrance into the FLEX Support Guidelines (FSG) is based on loss of all alternating current power and other equipment/system conditions, and is not based on potential weather conditions. The NRC staff notes that the licensee may adopt (as needed) the warning time procedures followed by the alternative trigger method allowed by Nuclear Energy Institute (NEI) 15-05 (NEI, 2015a).

The revised FHRR Attachment 2 (FENOC, 2016) provides the periods of inundation for LIP ranging from 0.1 hours to 7.5 hours depending on the locations within the power block area; however, the period of recession is not specified. The licensee used the two-dimensional numerical model described in the FHRR to determine the inundation periods. The NRC staff reviewed the licensee's model during its review of the revised FHRR and concluded that the licensee's modeling and the estimation of the period of inundation FED parameter values for LIP are appropriate for use in the MSA as they used present-day methodologies and regulatory guidance.

The NRC staff have noted that the other FED parameters as "not provided" in Table 4.2-1 for LIP, streams and rivers, and storm surge flood-causing mechanisms. By letter dated July 24, 2017, the licensee submitted its MSA (FENOC, 2017), which included these FED parameters for LIP, streams and rivers and storm surge. The NRC staff's review and conclusions regarding the FED parameters provided in the MSA will be documented in a separate staff assessment.

4.3 Associated Effects for Hazards Not Bounded by the CDB

The NRC staff reviewed the information provided in FENOC's 50.54(f) letter response (FENOC, 2015a, 2016) regarding the AE parameters for flood hazards not bounded by the CDB. The AE parameters related to water surface elevation (i.e., stillwater elevation with wind waves and runup effects) were provided in the FHRR and reviewed by the NRC staff, as documented in the

ISR letter. The AE parameters not directly associated with water surface elevation are discussed below and are summarized in Table 4.3-1.

The licensee estimated the water velocities using a two-dimensional numerical modeling method as described in the revised FHRR (FENOC, 2016). The NRC staff have noted the other AE parameters for LIP, streams and rivers, and storm surge flood-causing mechanisms as not provided in Table 4.3-1. By letter dated July 24, 2017, the licensee submitted the MSA, which included these AE parameters (FENOC, 2017). The NRC staff conclusions regarding the AE parameters provided in the MSA are documented in a separate staff assessment.

4.4 Conclusion

Based upon the preceding analysis, the NRC staff confirmed that the reevaluated flood hazard information defined in Section 4.1 is appropriate input to the additional assessments of plant response as described in the 50.54(f) letter (NRC, 2012a), COMSECY-15-0019 (NRC, 2015c), and associated guidance. Additional information for AE and FED parameters for LIP, streams and rivers, and storm surge were provided as part of the MSA (FENOC, 2017) and are documented in a separate report.

5.0 CONCLUSION

The NRC staff reviewed the information provided for the reevaluated flood-causing mechanisms for the Perry site. Based on the review of the information provided in FENOC's 50.54(f) response (FENOC, 2015a; 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 confirms the licensee's conclusions that (1) the reevaluated flood hazard results for LIP, streams and rivers, and storm surge are not bounded by the CDB flood hazards, (2) additional assessments of plant response will be performed for the LIP, streams and rivers, and storm surge flood-causing mechanisms, and (3) the reevaluated flood-causing mechanism information is appropriate input to additional assessments of plant response, as described in the 50.54(f) letter, COMSECY-15-0019 (NRC, 2015a), and associated guidance. At this time, the NRC staff has no additional information needs with respect to FENOC'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

Notes:

- 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 3.1-1. Summary of Controlling Flood-Causing Mechanisms

Reevaluated Flood-Causing Mechanisms and Associated Effects that May Exceed the Powerblock Elevation 620 ft. NGVD29[1]	ELEVATION [NGVD29]
Local Intense Precipitation and Associated Drainage	Power Block: 621.3 ft. Service/Emergency Service Water Pumphouse: 620.5 ft.

[1]Flood height and associated effects as defined in JLD-ISG-2012-05.

Table 3.1-2. Current Design Basis Flood Hazards

Flooding Mechanism	Stillwater Elevation [NGVD29]	Waves / Runup	Current Design Basis Flood (CDB) Elevation [NGVD29]	Reference
Local Intense Precipitation	620.5 ft.	Minimal	620.5 ft.	FHRR Rev 0, Section 2.1.1 & Table 2
Streams and Rivers				
Major Stream	624.0 ft.	N/A	624.0 ft.	FHRR, Rev 0, Section 2.1.2 & Table 2
Minor Stream	619.5 ft.	N/A	619.5 ft.	FHRR, Rev 0, Section 2.1.2 & Table 2
Failure of Dams and Onsite Water Control/Storage Structures	Not included in DB	Not included in DB	Not included in DB	FHRR Rev. 0 Section 2.1.3 & Table 2
Storm Surge High Water	580.5 ft	27.4 ft.	607.9 ft.	FHRR Rev. 0 Sections 2.1.4 and 2.1.8 & Table 2
Seiche				
Seiche is Combined with Storm Surge in CDB	Not included in DB	Not included in DB	Not included in DB	FHRR Rev. 0 Section 2.1.4 & Table 2
Tsunami	Not included in DB	Not included in DB	Not included in DB	FHRR Rev. 0 Section 2.1.5 & Table 2
Ice-Induced	No Impact on the Site Identified	No Impact on the Site Identified	No Impact on the Site Identified	FHRR Rev. 0 Section 2.1.6 & Table 2
Channel Migrations or Diversions	Not included in DB	Not included in DB	Not included in DB	FHRR Rev. 0 Section 2.1.7 & Table 2

N/A = Not applicable
Reported values are rounded to the nearest one-tenth of a foot.

Table 3.2-1. PMP and ssPMP depths developed by the licensee and the ORNL

Duration	5-min	15-min	30-min	1-h	6-h	12-h	24-h	48-h	72-h
Licensee's ssPMP (in.)	4.08	6.42	9.22	12.12	18.1	24	25.5	26.1	26.6
HMR (33 and 52) PMP (in.)	4.42	6.97	10.01	13.13	26.9	29.23	32.55	34.74	NA
ORNL's adjusted ssPMP (in.)	4.54	7.15	10.27	13.5	24.1	31.1	31.4	31.4	31.4

Table 4.1-1. Reevaluated Flood Hazards for Flood-Causing Mechanisms to be Evaluated in the Focused Evaluation or Integrated Assessment

Flood-Causing Mechanism	Stillwater Elevation, [NGVD29]	Waves / Runup	Reevaluated Flood Hazard [NGVD29]	Reference
Local Intense Precipitation and Associated Drainage				
Power Block	621.3 ft.	Minimal	621.3 ft.	FHRR Rev. 1, Section 3.8.4, & Table 5
North of Power Block at the Service Water Pumphouse and the Emergency Service Water Pumphouse Building	620.5 ft.	Minimal	620.5 ft.	FHRR Rev 1 Section 3.8.4
Streams and Rivers				
Major Stream	628.5 ft.	Not applicable	628.5 ft.	FHRR Rev 1, Section 3.1.4 and Table 5.
Minor Stream	619.7 ft.		619.7 ft.	
Storm Surge				
High Water: East of the Power Block Along the Shoreline Bluff Slopes (Probable Maximum Storm Surge Resulting from a Probable Maximum Wind Storm	581.9 ft	27.6 ft	609.5 ft	FHRR Rev1, Section 3.7.4 and Table 5.

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

Flood-Causing Mechanism	Time Available for Preparation for Flood Event*	Duration of Inundation of Site*	Time for Water to Recede from Site*
Local Intense Precipitation and Associated Drainage	Not provided (1)	0.1 to 7.5 h	Not provided
Streams and Rivers	Not provided	Not provided	Not provided
Storm Surge	Not provided	Not provided	Not provided

*Information to be provided as part of a future assessment.

(1) If needed, the licensee has the option to use NEI guideline 15-05 (NEI, 2015a) to estimate the warning time for LIP.

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

Associated Effects Factor	Local Intense Precipitation*	Streams and Rivers*	Storm Surge*
Hydrodynamic loading at plant grade	Not provided	Not provided	Not provided
Debris loading at plant grade	Not provided	Not provided	Not provided
Sediment loading at plant grade	Not provided	Not provided	Not provided
Sediment deposition and erosion	Not provided	Not provided	Not provided
Concurrent Conditions, including adverse weather	Not provided	Not provided	Not provided
Groundwater ingress	Not provided	Not provided	Not provided
Other pertinent factors (e.g., waterborne projectiles)	Not provided	Not provided	Not provided

*Information to be provided as part of a future assessment.

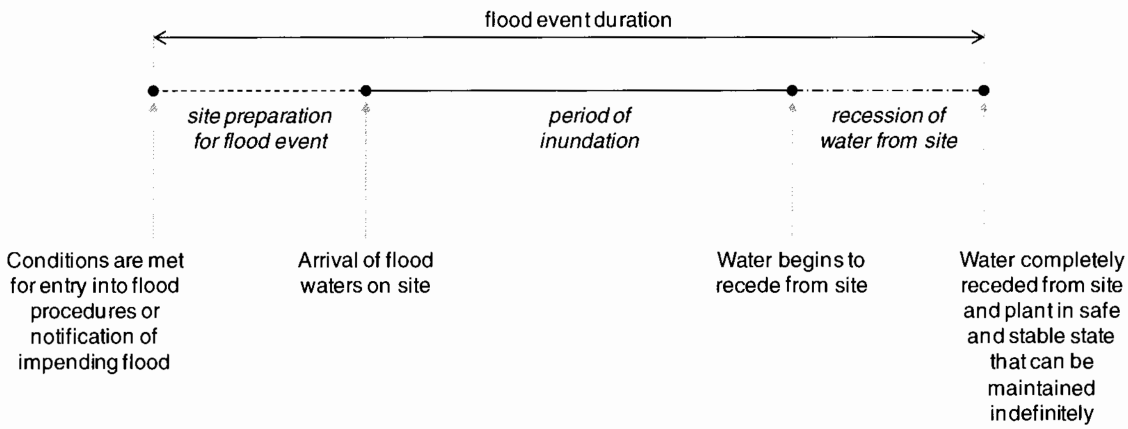

Figure 2.2-1. Flood Event Duration (NRC JLD-ISG-2012-05, Figure 6).

Figure 3.2-1. Perry site layout showing the Power Block and other areas (Service/Emergency Service Pump House and Circulating Water Pump House for Unit 1 and Unit 2), where the 83 door locations were evaluated in LIP analysis.

Figure 3.2-2. LIP FLO-2D model domain showing Major Stream, Minor Stream, Diversion Channel, Plant Access Road, Secondary Access Road and Depression Area.

Figure 3.3-1. Site layout showing Major Stream, Minor Stream, Diversion Channel (Re-aligned Channel), Secondary Access Road, and overbank flow (see the blue arrow) that would occur when the model is driven by the ORNL's ssPMP. (Modified from Figure 2.0.1, FHRR, Revision 1)

Summary of Audit Report corresponding to the Audit Plan Dated June 8, 2015 (ADAMS Accession No. ML15153A145)

I. BACKGROUND AND AUDIT BASIS:

By letter dated June 8, 2015 (ADAMS Accession No. ML15153A145), the NRC notified FENOC of the staff's plan to perform a regulatory audit of Perry's supporting calculations of the Flood Hazard Reevaluation Report. The technical audit was performed consistent with NRC Office of Nuclear Reactor Regulation, Office Instruction LIC-111, "Regulatory Audits," dated December 29, 2008 (ADAMS Accession No. ML082900195). This summary report provides the results of the audit performed by the staff.

II. AUDIT ACTIVITIES:

The NRC staff met with FENOC staff regarding the audit of the FHRRs (Rev. 0 and Rev. 1) on: 11/5/2015; 2/26/2016; and 6/21/2016. All interactions were teleconference calls.

NRC Audit Team – Points of Contact:

Christopher Cook	Aida Rivera	Richard Rivera-Lugo
Juan Uribe	Warren Sharp	Nebiyu Tiruneh
Laura Quin-Willingham	Kevin Quinlan	Brad Harvey

FENOC Audit Team – Points of Contact:

Phil Lashley	Kathleen Nevins

III. AUDIT SCOPE AND TECHNICAL EVALUATION:

During its review and audit, the NRC staff requested FENOC to provide additional information that would allow the staff to complete its review of the FHRRs. This additional information was only found to expand upon and clarify the information already provided in the initial and revised Perry FHRRs, and so those calculation packages were not docketed or cited. The information was made available to the NRC via an electronic reading room. The NRC staff did not rely directly on these calculation packages in its review. For completeness of information, Attachment 1 of this report contains a list that details the documents reviewed by the NRC staff, in part or in whole, as part of this audit. Attachment 2 of this report provides more details and 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 and/or mentioned in the staff assessment in more detail.

IV. CONCLUSION:

During the audit exit meeting held on June 21, 2016, the NRC stated that that no findings or open/unresolved items were found during the audit. The issuance of this document, containing the staff's review of the FHRR submittals, concludes the audit process for Perry.

ATTACHMENT 1

List of Documents Audited
Perry Nuclear Power Plant, Unit 1

ENERCON, 2015a, “Response to Information Needs: Information Need 1, “Streams and Rivers Flooding – Major Stream Outflow Hydrographs”, 5 pages, footer date of October 29, 2015, posted to Curtiss-Wright electronic reading room “FENOC Fukushima” on November 3, 2015

ENERCON, 2015b, “Response to Information Needs: Information Need 2, “Local Intense Precipitation – Methodology”, 2 pages, footer date of October 30, 2015, posted to Curtiss-Wright electronic reading room “FENOC Fukushima” on November 3, 2015

ENERCON, 2015c, “Response to Information Needs: Information Need 3, “Local Intense Precipitation – Unit Hydrograph”, 1 page, footer date of October 30, 2015, posted to Curtiss-Wright electronic reading room “FENOC Fukushima” on November 3, 2015

ENERCON, 2015d, “Response to Information Needs: Information Need 6, Combined Effects—Wave Runup”, 4 pages, document has footer date of October 29, 2015, posted to Curtiss-Wright electronic reading room “FENOC Fukushima” on November 3, 2015.

ENERCON, 2015e, “Response to Information Needs: Information Need 7, “Local Intense Precipitation – Site Specific PMP”, 1 page, footer date of October 29, 2015, posted to Curtiss-Wright electronic reading room “FENOC Fukushima” on November 4, 2015.

ENERCON, 2015f, “Response to Information Needs: Information Need 8, “Local Intense Precipitation – Site Specific PMP”, 3 pages, footer date of October 29, 2015, posted to Curtiss-Wright electronic reading room “FENOC Fukushima” on November 4, 2015.

ENERCON, 2015g, “Response to Information Needs: Information Need 9, “Local Intense Precipitation – Site Specific PMP”, 1 page, footer date of October 29, 2015, posted to Curtiss-Wright electronic reading room “FENOC Fukushima” on November 4, 2015.

ENERCON, 2015h, “Response to Information Needs: Information Need 10, “All Flood Causing Mechanisms – Comparison of Reevaluated Flood Hazard with Current Design Basis”, 2 pages, footer date of October 29, 2015, posted to Curtiss-Wright electronic reading room “FENOC Fukushima” on November 4, 2015.

ENERCON, 2015i, “Response to Information Needs: Information Need 11, “Input to Additional Assessment(s) – Mechanisms Considered”, 2 pages, footer date of November 3, 2015, posted to Curtiss-Wright electronic reading room “FENOC Fukushima” on November 4, 2015.

ENERCON, 2015j, "Response to Information Needs: Information Need 12, "Input to Additional Assessment(s) – Flood Height and Associated Effects", 2 pages, footer date of November 3, 2015, posted to Curtiss-Wright electronic reading room "FENOC Fukushima" on November 4, 2015.

ENERCON, 2015k, "Response to Information Needs: Information Need 13, "Hazard Input to the Additional Assessment(s) Flood Event Duration Parameters", 2 pages, footer date of November 3, 2015, posted to Curtiss-Wright electronic reading room "FENOC Fukushima" on November 4, 2015.

Electric Power Research Institute (EPRI), "Probable Maximum Precipitation Study for Wisconsin and Michigan, Final Report, Volume 1, Prepared by North American Weather Consultants, July 1993.

FENOC, 2004, "Calculation p45-081: Evaluation of Net Positive Suction Head (NPSH) and Submergence Requirements for the Emergency Service Water (EWE) System Pumps," 47 pages, signed on September 28, 2004, posted to Curtiss-Wright electronic reading room, "FENOC Fukushima" on May 28, 2015.

FENOC, 2014, "Storm Precipitation Analysis System (SPAS) for Storm #1344 SPAS Analysis," 9 pages, October 24, 2014, posted to Curtiss-Wright electronic reading room, "FENOC Fukushima" on March 16, 2016.

FENOC (FirstEnergy Nuclear Operating Company), 2015a, "Flood Hazard Reevaluation Report," Revision 0, Enclosure to Letter from Ernest J. Harkness to NRC Document Control Desk, Subject: "First Energy Nuclear Operating Company (FENOC) Response to NRC Request for Information Pursuant to 10 CFR 50.54(f) Regarding the Flooding Aspects of Recommendation 2.1 of the Near-Term Task Force (NTTF) Review of Insights from the Fukushima Dai-ichi Accident," March 10, 2015, ADAMS Accession No. ML15069A056 (Public).

FENOC, 2015b, "Calculation 50:36.000 Revision 0: PNPP Site-Specific All Season PMP," 68 pages, signed on February 16, 2015, posted to Curtiss-Wright electronic reading room, "FENOC Fukushima" on May 28, 2015.

FENOC, 2015c, "Calculation 50:37.000 Revision 0: PNPP Site-Specific Cool-Season PMP," 3266 pages, signed on February 16, 2015, posted to Curtiss-Wright electronic reading room, "FENOC Fukushima" on May 28, 2015.

FENOC, 2015d, "Calculation 50:38.000 Revision 0: PNPP Major Stream All-Season Probable Maximum Flood," 255 pages, signed on February 17, 2015, posted to Curtiss-Wright electronic reading room, "FENOC Fukushima" on May 28, 2015.

FENOC, 2015e, "Calculation 50:39.000 Revision 0: PNPP Site-Specific All Season PMP," 68 pages, signed on February 17, 2015, posted to Curtiss-Wright electronic reading room, "FENOC Fukushima" on May 28, 2015.

FENOC, 2015f, "Calculation 50:40.000 Revision 0: PNPP Minor Stream All-Season Maximum Flood," 592 pages, signed on February 23, 2015, posted to Curtiss-Wright electronic reading room, "FENOC Fukushima" on May 28, 2015.

FENOC, 2015g, “Calculation 50:41.000 Revision 0: PNPP Minor Stream Cool-Season Probable Maximum Flood,” 575 pages, signed on February 23, 2015, posted to Curtiss-Wright electronic reading room, “FENOC Fukushima” on May 28, 2015.

FENOC, 2015h, “Calculation 50:42.000 Revision 0: PNPP Effects of Local Intense Precipitation Analysis,” 927 pages, signed on February 23, 2015, posted to Curtiss-Wright electronic reading room, “FENOC Fukushima” on May 28, 2015.

FENOC, 2015i, “Calculation 50:43.000 Revision 0: PNPP Dams Assessment,” 47 pages, signed on February 16, 2015, posted to Curtiss-Wright electronic reading room, “FENOC Fukushima” on May 28, 2015.

FENOC, 2015j, “Calculation 50:44.000 Revision 0: PNPP Ice Jam and Channel Migration Assessment,” 70 pages, signed on February 23, 2015, posted to Curtiss-Wright electronic reading room, “FENOC Fukushima” on May 28, 2015.

FENOC, 2015k, “Calculation 50:45.000 Revision 0: PNPP Wind Climatology,” 115 pages, signed on February 16, 2015, posted to Curtiss-Wright electronic reading room, “FENOC Fukushima” on May 28, 2015.

FENOC, 2015l, “Calculation 50:46.000 Revision 0: PNPP Surge and Seiche Screening,” 157 pages, signed on February 17, 2015, posted to Curtiss-Wright electronic reading room, “FENOC Fukushima” on May 28, 2015.

FENOC, 2015m, “Calculation 50:47.000 Revision 0: PNPP Surge and Seiche Analysis,” 148 pages, signed on February 17, 2015, posted to Curtiss-Wright electronic reading room, “FENOC Fukushima” on May 28, 2015.

FENOC, 2015n, “Calculation 50:48.000 Revision 0: PNPP Tsunami Assessment,” 103 pages, signed on February 17, 2015, posted to Curtiss-Wright electronic reading room, “FENOC Fukushima” on May 28, 2015.

FENOC, 2015o, “Calculation 50:52.000 Revision 0: PNPP Rainfall Runoff GIS Analysis,” 50 pages, signed on February 16, 2015, posted to Curtiss-Wright electronic reading room, “FENOC Fukushima” on May 28, 2015.

FENOC, 2015p, “Calculation 50:53.000 Revision 0: Surge and Seiche Analysis,” 148 pages, signed on February 17, 2015, posted to Curtiss-Wright electronic reading room, “FENOC Fukushima” on May 28, 2015.

FENOC, 2015q, “Calculation 50:54.000 Revision 0: Surge and Seiche Analysis,” 148 pages, signed on February 17, 2015, posted to Curtiss-Wright electronic reading room, “FENOC Fukushima” on May 28, 2015.

FENOC, 2015r, “Calculation 50:55.000 Revision 0: PNPP Combined Events,” 331 pages, signed on February 23, 2015, posted to Curtiss-Wright electronic reading room, “FENOC Fukushima” on May 28, 2015.

FENOC, 2015r, “Calculation 50:59.000 Revision 0: PNPP Site-Specific All-Season Sub-Hour Probable Maximum Precipitation Analysis for 1-10 Square Miles,” 217 pages, signed on February 16, 2015, posted to Curtiss-Wright electronic reading room, “FENOC Fukushima” on May 28, 2015.

FENOC, 2015s, “Calculation 50:60.000 Revision 0: PNPP Site-Specific Cool-Season Probable Maximum (Rainfall) Precipitation Analysis,” 201 pages, signed on February 16, 2015, posted to Curtiss-Wright electronic reading room, “FENOC Fukushima” on May 28, 2015.

FENOC, 2016a, “Flood Hazard Reevaluation Report,” Revision 1, Enclosure to Letter from Frank R. Payne to NRC Document Control Room, Subject: “Revision of Flood Hazard Reevaluation Report in Response to NRC Request for Information Pursuant to 10 CFR 50.54(f) Regarding the Flooding Aspects of Recommendation 2.1 of the Near-Term Task Force (NTTF) Review of Insights from the Fukushima Dai-ichi Accident (TAC No. MF6099), March 24, 2016, ADAMS Accession No. ML16084A871 (Public).

FENOC, 2016b, “Hard Drive with Electronic Information,” Input and Output files and model runs for Flood Hazard Reevaluation Report, Revision 1, Enclosure to Letter from David B. Hamilton, to NRC Document Control Desk, Subject: Response to the Request for Additional Information Regarding the Near-Term Task Force (NTTF) Recommendation 2.1 Flood Hazard Reevaluation Report (CAC No. MF6099), November 9, 2016, ADAMS Accession No. ML16328A439 (Public).

FENOC, 2016c, “Information Need 2-Storm Representative Dew Point Adjustment,” Folder posted to Curtiss-Wright electronic reading room, “FENOC Fukushima” on February 15, 2016.

FENOC, 2016d, “Information Need 5-Simpson-KY-1939,” Folder posted to Curtiss-Wright electronic reading room, “FENOC Fukushima” on February 15, 2016.

FENOC, 2016e, “IN4 Perry_CollegeHill_OH_TD_Review_v1,” 5 pages, Excel file posted to Curtiss-Wright electronic reading room, “FENOC Fukushima” on February 15, 2016.

FENOC, 2016f, “IN3 Perry_Boyden_IA_TD_Review_v1,” 6 pages, Excel file posted to Curtiss-Wright electronic reading room, “FENOC Fukushima” on February 15, 2016.

FENOC, 2016g, “Information Needs 1-6 for Flood Hazard Reevaluation of Perry Nuclear Power Plant,” 20 pages, Responses to ssPMP Information Needs No. 1-6, posted to Curtiss-Wright electronic reading room, “FENOC Fukushima” on February 15, 2016.

FENOC, 2016h, “Telecon 06-21-20116,” Folder posted to Curtiss-Wright electronic reading room, “FENOC Fukushima” on February 15, 2016. Contains 001-Modifications (Major), 002-Modifications (Major), 003- Access Road, 004- Software1, and 005-Softwware2.

FENOC, 2016i, “Clarification Request 2 (9-28-2016),“ 1 page, Adobe pdf file posted Curtiss-Wright electronic reading room, “FENOC Fukushima” on October 10, 2016.

FENOC, 2016j, “Clarification Request 3 (9-28-2016),“ 1 page, Adobe pdf file posted Curtiss-Wright electronic reading room, “FENOC Fukushima” on October 10, 2016.

Great Lakes Construction Company, 2015, Project 853 15, Perry Nuclear Power Plant as Built Asphalt Driveway, Prepared for FENOC, November 16, 2015.

National Oceanic and Atmospheric Administration (NOAA), 1941, “Maximum Possible Precipitation Ohio River Basin above Pittsburgh, Hydrometeorological Report No. 2, prepared by the Weather Bureau, Department of Commerce in cooperation with the U.S. Army Corps of Engineers, June 16, 1941.

U.S. Army Corps of Engineers (USACE, 2015), Wave Windcast Model Domains for Great Lakes, Website http://wis.usace.army.mil/hindcast.shtml?dmn-lakesWIS, date accessed 10/21/2015.

Attachment 2

Summary of Information Reviewed

Perry Nuclear Power Plant, Unit 1

Information Need No.	Reference No./ Transmittal Date[1]	Information Need Description	Response Summary
1	1	**Streams and Rivers Flooding – Major Stream outflow hydrographs** Background: The Flood Hazard Reevaluation Report (FHRR) reports (FENOC, 2015a) that the major stream is not directly adjacent to Perry Nuclear Power Plant (Perry) safety-related structures; however, overtopping at the rail line bridge structure results in overflow from a major stream that contributes to flooding in the minor stream and the local intense precipitation (LIP) modeling area. The overtopping at the rail line bridge causes backwater to accumulate. Some of the accumulated backwater flows towards the plant site in the north, and some overflows the access road further to the east and flows towards the minor stream watershed. The peak flow into the plant site is 74 cubic feet per second (cfs), and the peak flow into the minor stream watershed is 1,754 cfs. The licensee considered the flow into the plant site in the LIP modeling analysis and the flow into the minor stream watershed in the streams and rivers flooding analysis.	The licensee submitted a revised FHRR (FENOC, 2016a) with significant engineering modification of Major Stream. With these modifications, the Major Stream does not contribute to the flooding into the power block area and the Minor Stream, and thus this information need is resolved.

[1] The reference number was the info need number assigned when originally transmitted to the licensee.

Information Need No.	Reference No./ Transmittal Date[1]	Information Need Description	Response Summary
		The staff visually inspected imagery of the site and proposes the possibility that the overtopping flow at the rail line structure at the major stream could move in any direction. If all overtopping flow moves in only one direction (either to the power plant site or to the minor stream), the impact could be higher than that reported in the FHRR. Request: Provide the rationale for why the accumulated backwater, as a result of overtopping at the rail line bridge structure, flows in two directions. The rationale could include a figure that clearly shows the rail line bridge with flow accumulation area and flow direction calculated based on a topographic (contour) map.	
2	2	**Local Intense Precipitation – Methodology** Background: The licensee used the U.S. Army Corps of Engineers (USACE) Hydrologic Engineering Center - Hydrologic Modeling System (HEC-HMS) model for the LIP analysis, modeling four sub-basins as four reservoirs (FENOC, 2015a). HEC-HMS calculates water surface elevations (WSE) for each reservoir (sub-basin) using a reservoir storage-elevation (rating) curve, where reservoir storage is calculated as functions of inflow and outflow from a reservoir. This method calculates a single, uniform WSE value for each sub-basin. The spatial variation of WSE inside the sub-basin is not considered. However, depending on the sub-basin characteristics (slope, aspect,	This information need is resolved as a result of the updated LIP analysis using 2-D hydraulic and hydrologic model, FLO-2D, in the FHRR Revision 1 (FENOC, 2016a) instead of HEC-HMS model in the FHRR Revision 0 (FENOC, 2015a).

Information Need No.	Reference No./ Transmittal Date[1]	Information Need Description	Response Summary
		surface roughness due to land type, etc.), WSEs would be expected to vary at different locations within a sub-basin. Further, the man-made structures, if present in the sub-basin, would constrain or obstruct the flow making the flow depth higher in some areas than in other areas. Request: Provide rationale for the approach of HEC-HMS hydrologic modeling with an application of a rating curve is more conservative than a 2-D hydraulic modeling approach, and that a uniform WSE estimated for each reservoir (sub-basin) would reasonably reflect the flooding effects near the Perry safety-related structures.	
3	**3**	**Local Intense Precipitation – Unit Hydrograph** Background: The FHRR reports (FENOC, 2015a) that to translate the rainfall into runoff, a synthetic unit hydrograph was developed using an empirical method; and, no adjustment of the unit hydrograph was made to account for the effects of a nonlinear basin response. A derived unit hydrograph may not always represent hydrometeorological conditions that would prevail during the probable maximum flood (PMF), and thus non-linearity adjustments should be made to the PMF hydrographs per recommendations presented in NUREG/CR-7046 (NRC, 2011).	This information need is resolved as a result of the updated LIP analysis using 2-D hydraulic and hydrologic model, FLO-2D, in the FHRR Revision 1 (FENOC, 2016a) instead of HEC-HMS model in the FHRR Revision 0 (FENOC, 2015a).

Information Need No.	Reference No./ Transmittal Date[1]	Information Need Description	Response Summary
		Request: Discuss and clarify why the unit hydrograph is not adjusted to account for the effects of a nonlinear basin response.	
4	4	**Local Intense Precipitation – Spillways and Dam Tops** Background: The licensee used an HEC-HMS model for the LIP analysis (FENOC, 2015a). Four sub-basins are modeled as four reservoirs, and outflow from each reservoir is modeled using broad-crested spillways and dam tops. All four reservoirs are connected, and flows from the three upstream reservoirs contribute to the flooding effects at the fourth downstream reservoir where all PERRY safety-related structures are located. To calculate the direction of flow and the volume of outflow from a reservoir, it is important to understand the locations as well as the elevations and lengths of the outlet structures in the reservoirs. In the FHRR, neither the outlet structure locations, nor the determination of lengths and elevations of these structures were clearly described. Request: Provide a) a figure showing the four reservoirs, and indicating the locations and lengths of the spillways and the dam tops that control the releases from the reservoirs; and, b) provide the basis for the determination of elevations and lengths of spillways and dam tops.	This information need is resolved as a result of the updated LIP analysis using 2-D hydraulic and hydrologic model, FLO-2D, in the FHRR Revision 1 (FENOC, 2016a) instead of HEC-HMS model in the FHRR Revision 0 (FENOC, 2015a).

Information Need No.	Reference No./ Transmittal Date[1]	Information Need Description	Response Summary
5	5	**Local Intense Precipitation – Spillways and Dam Tops** Background: For broad-crested weirs, HEC-HMS calculates the reservoir outflow as: $Q = CLH^{1.5}$ where, Q = flow rate over the weir (cfs), C = dimensional discharge coefficient ($ft^{0.5}/s$), which ranges from 2.6 to 4.0 depending on the shape of the weir, L= weir length (ft), and H =total energy head over the crest (ft). The model input data show that the licensee chose a C value of 2.6 for all spillways and dam tops. The C value chosen is in the lower end of its range, and the lower C would result in less flow towards the fourth reservoir where all PERRY safety-related structures are located. Therefore, selection of a low value of C may not be a conservative approach. Request: Provide the rationale for the C value used in the HEC-HMS model results in conservatism. The rationale could include a sensitivity analysis choosing the larger C value in reservoir modeling.	This information need is resolved as a result of the updated LIP analysis using 2-D hydraulic and hydrologic model, FLO-2D, in the FHRR Revision 1 (FENOC, 2016a) instead of HEC-HMS model in the FHRR Revision 0 (FENOC, 2015a).
6	6	**Combined Effects – Wave Runup** Background: Wind wave effects are reported in the FHRR for Lake Erie under surge conditions based on the use of Delft 3D-SWAN software; and, documentation of that use is in Calculation	The licensee stated in the response in the ERR that in Calculation 50:54.000 "PERRY Surge and Seiche Calibration", a Delft3d-SWAN calibration was made to April 1998 and October 2010 storm events (ENERCON, 2015a). The licensee replicated the previous simulation for PMSS

Information Need No.	Reference No./ Transmittal Date[1]	Information Need Description	Response Summary
		50:47.000, Rev 0 (FENOC, 2015b) with results being used in subsequent Calculation 50:55.000, Revision 0 (FENOC, 2015c). This information is needed for staff's review and preparation of the staff assessment. Wave effects (runup) are evaluated as a combined event with Lake Erie surge. Electronic reading room (ERR) Document Calculation 50:47.000, Revision 0 (FENOC, 2015b) describes the application of the Delft 3D-SWAN software to Lake Erie for the purpose of estimating wave parameters along the lake's shore near the site using the software capability to develop and transform wind and wave across the lake and towards the lakeshore near the site. Figure 4.7 of Calculation 50:47.000, Rev 0 (FENOC, 2015b) shows the significant attenuation of the wave height as it approaches the shore as estimated by the software application (see USACE Wave Information Studies at http://wis.usace.army.mil/) (USACE, 2015). There are Wave Information Studies (WIS) Stations (92056, 92056, and 92057) near the site from which significant wave heights and peak wave periods have been developed for historical extreme events. These values could be used to evaluate the performance of the software application and a figure could be added similar to Calculation 50:47.000, Rev 0 (FENOC, 2015b), Figure 4.7 to demonstrate model skill and conservatism in its estimation of wave parameters that were further used to calculate wave runup at the site.	(Calculation 50:47.000 Rev. 0; FENOC, 2015c) to obtain model results for WIS Stations 92056 and 92057. In its response, the licensee provides a maximum wave height comparison between the Delft3D-SWAN model and observations from WIS Stations 92056 and 92057 for an October 30, 2012 event. The licensee also provides a maximum wave period comparison between the Delft 3D-SWAN model and observations from WIS Stations 92056 and 92057 for a December, 1987 event (ENERCON, 2015a). The licensee stated that, based on the review of the results of these efforts, that the Lake Erie Delft3D-SWAN model is capable of reproducing observed significant wave heights and wave periods (ENERCON, 2015a). The NRC staff reviewed the response and concluded the information was sufficient to resolve the information need request.

Information Need No.	Reference No./ Transmittal Date[1]	Information Need Description	Response Summary
		Request: Provide a comparison of nearshore wave parameters derived from the simulations described in the FHRR with other estimates which are based on historical observation made for extreme surge events, or describe other wave parameter evaluations that were conducted. The WIS Station extreme event results are one such source of information that could be used for this purpose.	
7	7	**Local Intense Precipitation – Site Specific PMP** Background: For the Perry FHRR (FENOC, 2105a), the licensee chose to use a site-specific probable maximum precipitation (ssPMP) estimate for reevaluating certain flood hazards, rather than using a probable maximum precipitation (PMP) from the National Weather Service (NWS) hydrometeorological reports (HMRs) as detailed in NUREG/CR-7046 (NRC, 2011). The NRC staff determined that a large enough difference in resulting WSE exists between the analyses using the ssPMP and NWS HMRs, warranting a more detailed review of the ssPMP. To aid in the NRCs assessment of the FHRR the following information is requested from the licensee. Request: The staff requests the following files be submitted on the docket for use in the staff assessment: a. Applied Weather Associates (AWA) ssPMP Main Report for Perry Nuclear Power Plant	The requested information was provided to the NRC staff via the ERR (ENERCON, 2015b)

Information Need No.	Reference No./ Transmittal Date[1]	Information Need Description	Response Summary
		This request is for the complete AWA ssPMP report in PDF format, including all appendices. b. AWA ssPMP LIP Calculation Package for Perry Nuclear Power Plant This request is for the complete calculation package for site-specific LIP calculations, including all appendices.	
8	**8**	**<u>Local Intense Precipitation – Site Specific PMP</u>** <u>Background</u>: For the Perry FHRR (FENOC, 2015a), the licensee chose to use a ssPMP estimate for reevaluating certain flood hazards, rather than using a PMP from the NWS HMRs as detailed in NUREG/CR-7046 (NRC, 2011). The NRC staff determined that a large enough difference in resulting WSE exists between the analyses using the ssPMPs and NWS HMRs, warranting a more detailed review of the ssPMP. To aid in the NRCs assessment of the FHRR the following information is requested from the licensee. <u>Request</u>: The staff requests the following files be provided on a DVD for staff review as part of the audit:	The requested information was provided to the NRC staff via the ERR (ENERCON, 2015c)

		a. The complete storm analysis information for the LIP ssPMP. Provide the analysis information for all short list storms that were used for the LIP ssPMP calculation (such as those reported in the previous AWA reports). The detailed storm analysis information should include: • Storm spreadsheet • Moisture inflow map • 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 b. 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 was included/excluded based on previous Federal Energy Regulatory Commission Board of Consultants (FERC BOC) or state	

Information Need No.	Reference No./ Transmittal Date[1]	Information Need Description	Response Summary
		PMP study conclusions, the exact reference should be clearly stated. c. 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 submitted to NRC on May 7, 2015). If publicly-accessible dew point data was used (e.g., National Climatic Data Center (NCDC) Integrated Surface Database (ISD)), the unique station identifier (e.g., U.S. Air Force (USAF), Weather-Bureau-Army-Navy (WBAN), and/or ICAO call sign) 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 was used as a surrogate of surface dew point	

Information Need No.	Reference No./ Transmittal Date[1]	Information Need Description	Response Summary
		observation, the sea surface temperature observation should be provided. d. AWA Calculation Sheet of 100-year (yr) Dew Point Climatology At locations where the 100-yr 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-yr dew point at the selected gauge should be provided for review.	
9	9	**<u>Streams and Rivers – Site Specific PMP</u>** <u>Background</u>: For the Perry FHRR (FENOC, 2015a), the licensee chose to use a ssPMP estimate for reevaluating certain flood hazards, rather than using a PMP from the NWS HMRs as detailed in NUREG/CR-7046 (NRC, 2011). The NRC staff determined that a large enough difference in resulting WSE exists between the analyses using the ssPMPs and NWS HMRs, warranting a more detailed review of the ssPMP. To aid in the NRCs	The requested information was provided to the NRC staff via the ERR (ENERCON, 2015d)

Information Need No.	Reference No./ Transmittal Date[1]	Information Need Description	Response Summary
		assessment of the FHRR the following information is requested from the licensee. Request: The staff requests the following files be provided on a DVD for staff review as part of the audit: a. The complete storm analysis information for Streams and Rivers ssPMP Provide the analysis information for all short list storms that were used for streams and rivers ssPMP calculation (such as those reported in the previous AWA reports). The detailed storm analysis information should include: • Storm spreadsheet • Moisture inflow map • 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 b. 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	

Information Need No.	Reference No./ Transmittal Date[1]	Information Need Description	Response Summary
		storms that have been considered during the development of the Streams and Rivers 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 was included/excluded based on previous FERC BOC or state PMP study conclusions, the exact reference should be clearly stated. c. 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 submitted to NRC on May 7, 2015). If publicly-accessible dew point data was 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	

Information Need No.	Reference No./ Transmittal Date[1]	Information Need Description	Response Summary
		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 was used as a surrogate of surface dew point observation, the sea surface temperature observation should be provided. d. AWA Calculation Sheet of 100-yr Dew Point Climatology At locations where the 100-yr 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-yr dew point at the selected gauge should be provided for review. e. Storm Envelopment files The licensee should submit (1) Excel files detailing the depth-area-duration envelopment data and	

Information Need No.	Reference No./ Transmittal Date[1]	Information Need Description	Response Summary
		curves derived at various individual grid points used for analyzing the Indian Point Energy Complex (IPEC) watershed-scale PMP, and (2) GIS layers showing spatial envelopment across the IPEC watershed	
10	10	**All Flood Causing Mechanisms – Comparison of Reevaluated Flood Hazard with Current Design Basis** Background: Recommendation 2.1 of the 50.54(f) letter provides instructions for the Flood Hazard Reevaluation Report (FHRR) (NRC, 2012a). Under Section 1, Hazard Reevaluation Report, Items c and d, licensees are requested to perform: 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	The licensee made consistent use of the CDB in FHRR Revision 1 (FENOC, 2016a), and therefore, this information need is resolved.

Information Need No.	Reference No./ Transmittal Date[1]	Information Need Description	Response Summary
		completion of the integrated assessment described below, if necessary. The Perry FHRR mentions in the text a comparison of the reevaluated flood hazards with the current licensing basis and then in tabular form compares with the CDB for each flood hazard mechanism. FHRR Section 4 and Table 2 summarizes this comparison. <u>Request</u>: Clarify and where necessary correct the description and/or comparison of the reevaluated flood hazard to the CDB for each flood hazard mechanism throughout the report. (There may be only one location in the text that needs attention.)	
11	**11**	**<u>Input to Additional Assessment(s) - Mechanisms considered</u>** The NRC staff noted from Section 4 and Table 2 of the FHRR that the reevaluated site flood levels exceed the corresponding design-basis flood levels, which trigger an additional assessment. Therefore, the licensee is requested to clarify which flood hazard mechanisms will be included as part of an additional assessment(s) as described in the 50.54(f) letter (NRC, 2012a) and the "Mitigating Strategies and Flood Hazard Reevaluation Action Plan" (COMSECY-15-0019) (NRC, 2015a).	Resolved through the FHRR Revision 1 submittal on March 10, 2015 (FENOC, 2016a).
12	**12**	**<u>Input to Additional Assessment(s) - flood height and associated effects</u>**	The licensee did not provide the requested information in FHRR Revision 1 (FENOC, 2016a), but instead the licensee

Information Need No.	Reference No./ Transmittal Date[1]	Information Need Description	Response Summary
		Background: COMSECY-15-0019 requests the licensee to perform an additional assessment(s) of the plant's response to the reevaluated hazard if the reevaluated flood hazard is not bounded by the current design basis (NRC, 2015a). Flood scenario parameters from the flood hazard reevaluation serve as the input to the additional assessment(s). To support efficient and effective evaluations for the additional assessment(s), staff will review flood scenario parameters as part of the flood hazard reevaluation and document results of the review as part of the staff assessment of the flood hazard reevaluation. Request: The licensee is requested to provide the flood height and associated effects (as defined in Section 9 of JLD-ISG-2012-05; NRC, 2012b) that are not described in the flood hazard reevaluation report for mechanisms that trigger an additional assessment. This includes the following quantified information for each mechanism (as applicable): • Hydrodynamic loading, including debris, • Effects caused by sediment deposition and erosion (e.g., flow velocities, scour), • Concurrent site conditions, including adverse weather, • Groundwater ingress, and • Other pertinent factors.	deferred providing this information until the MSA submittal. The MSA was received on July 24, 2017 (FENOC, 2017) and the staff is currently reviewing the MSA.

Information Need No.	Reference No./ Transmittal Date[1]	Information Need Description	Response Summary
13	13	**Hazard input to the Additional Assessment(s) - flood event duration parameters** Background: COMSECY-15-0019 requests the licensee to perform an additional assessment(s) of the plant's response to the reevaluated hazard if the reevaluated flood hazard is not bounded by the current design basis (NRC, 2015a). Flood scenario parameters from the flood hazard reevaluation serve as the input to the additional assessment(s). To support efficient and effective evaluations for the additional assessment(s), staff will review flood scenario parameters as part of the flood hazard reevaluation and document results of the review as part of the staff assessment of the flood hazard reevaluation. Request: The licensee is requested to provide the applicable flood event duration parameters (see definition and Figure 6 of the Guidance for Performing an Integrated Assessment, JLD-ISG-2012-05; NRC, 2012b) associated with mechanisms that trigger an additional assessment using the results of the flood hazard reevaluation. This includes (as applicable) the warning time the site will have to prepare for the event (e.g., the time between notification of an impending flood event and arrival of floodwaters on site) and the period of time the site is inundated for the mechanisms that are not bounded by the current design basis. The licensee is also requested to provide the basis or source of information for the flood event duration,	The licensee did not provide all of the requested information in FHRR Revision 1 (FENOC, 2016a). Warning times and recession times were not provided for LIP, streams and rivers, and storm surge. The staff expects that information would be provided in the MSA. The MSA was received on July 24, 2017 (FENOC, 2017), and the NRC staff is currently reviewing the MSA.

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<tr><th>Information Need No.</th><th>Reference No./ Transmittal Date[1]</th><th>Information Need Description</th><th>Response Summary</th></tr>
<tr><td></td><td></td><td>which may include a description of relevant forecasting methods (e.g., products from local, regional, or national weather forecasting centers) and/or timing information derived from the hazard analysis.</td><td></td></tr>
<tr><td>14</td><td>1</td><td>
7.0 <u>WARM-SEASON SSPMP ESTIMATES FROM OHIO STATEWIDE PMP STUDY</u>

<u>Background</u>: According to Section 3.1.3 of the FHRR (FENOC, 2015a), the warm-season ssPMP was estimated using the Ohio statewide PMP study results for durations from 6- to 72-hour (h) and the Perry site-specific study results for durations of 1-h and below. The Perry point (1-mi^2) precipitation values taken from the Ohio statewide PMP study for durations of 6-, 12-, 24-, 48-, and 72-h are reported in Table 4.1 of Calculation No. 50:36.000 (FENOC, 2015d). The NRC staff compared these ssPMP values with the short list storm adjusted depth-area-duration (DAD) values for LIP (reported in Attachment 1 of Calculation No. 50:59.000) and noticed two storms for which the adjusted DAD values appear to exceed the values estimated from the Ohio statewide PMP study. The table below highlights these instances.

<table>
<tr><th rowspan="2">Storm</th><th colspan="3">1-mi^2 PMP Value (inches)</th></tr>
<tr><th>6-h</th><th>12-h</th><th>24-h</th></tr>
<tr><td>Ohio Statewide PMP Value @ Perry location</td><td>18.1</td><td>24</td><td>25.5</td></tr>
</table>
</td><td>
The licensee explained (FENOC, 2015d) that the differences noted by NRC staff are the result of differences in PMP computed using the Perry site-specific information versus using PMP derived using the entire domain covering the state of Ohio. The licensee explained that the primary factors contributing to these differences are 1) elevation differences and 2) smoothing, which result from the gridded approach used in the Ohio statewide PMP study and are described in more detail here:

• The difference in elevation results from a single elevation being used for each grid in the Ohio study (900 ft at grid point 15 and 1,000 ft. at grid point 16, for an average elevation of 950 ft), compared to specific elevation data being used for the ssPMP evaluation for Perry (600 ft.). The licensee claims that this 350 ft. difference accounts for approximately 3-4% of the 6.6% difference noted.
• The difference in smoothing results from the Ohio study splitting the statewide domain into 23 grid points and spatially smoothing the PMP. The licensee claims that this difference accounts for approximately 3% of the 6.6% difference noted.

The licensee also stated that the Boyden, IA storm has been reanalyzed since the completion of the Ohio study. The
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<tr><th>Information Need No.</th><th>Reference No./ Transmittal Date[1]</th><th>Information Need Description</th><th>Response Summary</th></tr>
<tr><td></td><td></td><td>
<table>
<tr><td>(from Calculation No. 50:36.000, Table 4.1)</td><td></td><td></td><td></td></tr>
<tr><td>Boyden, IA
(from Calculation No. 50:59.000, Attachment 1)</td><td>19.3 (+6.6%)</td><td>25.0 (+4.2%)</td><td></td></tr>
<tr><td>College Hill, OH
(from Calculation No. 50:59.000, Attachment 1)</td><td></td><td></td><td>25.7 (+0.8%)</td></tr>
</table>

Request: Clarify why the site-specific storm analyses conducted for the Boyden, IA and College Hill, OH storms appear to exceed the ssPMP values used in the Perry evaluation. If corrections to the ssPMP values are warranted, provide updated storm calculation and envelopment curves, and, if needed, updated flooding simulations for the LIP flood and warm-season PMF with combined effects.</td><td>licensee noted that the Storm Precipitation Analysis System (SPAS) reanalysis resulted in a slight change to the DAD values for Boyden and that if the SPAS values were used, the Boyden DAD values would be slightly less than the PMP from the Ohio study. Table 1 of the response indicated:

• The observed 6-h, 1-mi^2 DAD for Boyden is 2.5% lower when using the reanalysis compared to the original USACE observed data.
• The observed 12-h, 1-mi^2 DAD for Boyden is 1.3% lower when using the reanalysis compared to the original USACE observed data.
• The observed 24-h, 1-mi^2 DAD for Boyden is 0.1% higher when using the reanalysis compared to the original USACE observed data.

The licensee's response noted that the Boyden, IA storm is not controlling for LIP (1-h, 1-mi^2). However, the original information need targeted the warm-season ssPMP (1-mi^2 PMP for durations above 6 hours), since the point PMP is used for evaluating flooding of the small Perry watershed and the site-specific evaluation exceeds the Ohio study for 6-h, 12-h, and 24-h. The data provided by the licensee and confirmed by the staff indicated that the PMP at shorter durations; however, will control in the case of Perry.

The NRC staff reviewed the licensee's response and determined the information provided was sufficient to resolve the information need request.</td></tr>
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Information Need No.	Reference No./ Transmittal Date[1]	Information Need Description	Response Summary
15	2	8.0 STORM REPRESENTATIVE DEW POINT ADJUSTMENT Background: As described in the AWA Audit report (Section 2b [NRC,2015b]), for storms previously analyzed by the National Weather Service with a 12-h persisting dew point temperature recorded, a 7° F adjustment was made to convert from a 12-h persisting dew point to a maximum 6-h average dew point. Following a demonstration during the audit, "the staff noted that the choice of what storm representative dew point temperature to apply had an effect on the in-place moisture maximization result" (Section 2b). The NRC independently reviewed dew point temperature data for various PMP-scale storms and determined that a 7° F adjustment may not be as conservative for converting a 12-h persisting dew point to a maximum 6-h average dew point for LIP-type storms. Instead, a 2° F adjustment was found to yield a more conservative PMP estimate when compared to using a 7° F adjustment. Request: Provide the technical basis for the use of a 7° F adjustment for converting a 12-h persisting dew point to a maximum 6-h average dew point. As a part of the response, demonstrate how the 7° F adjustment was determined and provide associated material (calculations, documentation, etc.) on the ERR.	The licensee defended its use of a 7° F adjustment for LIP-type storms (thunderstorm or mesoscale convective complex [MCC]) and a 2° F adjustment for general PMP storms (or synoptic) was reasonable (FENOC, 2015d). The licensee applied a 2° F to general and tropical storm events in which rainfall occurs over a longer time period (generally 24+ hours) and applied a 7° F adjustment to local storms which resemble thunderstorms of MCCs and have rainfall occurring over short time periods (generally 6 or fewer hours). The licensee stated that some storms have patterns more closely resembling a 12-h duration for which the 12-h 100-yr recurrence interval dew point climatology is used. The licensee stated that in these cases, the storm type (general or local) was considered when applying an adjustment factor. During an audit held on February 26, 2016, the licensee confirmed that members of the USACE and NWS were involved in the review of the 1993 EPRI study, which first recommended the dew point adjustment factors, and that the USACE was involved in review of the Wyoming statewide study, in which these adjustment factors were reviewed again due to the potential for differing storm dynamics. The licensee confirmed that some of the Perry short list storms were included in the 1993 EPRI study to evaluate the adjustment factors and acknowledged that the 7° F adjustment was assumed applicable for all MCC storms. Not all of the Perry short list storms were evaluated to assess the appropriateness of the 7° F adjustment.

Information Need No.	Reference No./ Transmittal Date[1]	Information Need Description	Response Summary
			Based on the lack of substantial evidence supporting the 7° F adjustment used by the licensee, the staff performed additional sensitivity analysis using the AWA ssPMP and generated a staff-derived ssPMP. The NRC staff reviewed the licensee's response and with the addition of the sensitivity runs determined the information provided was sufficient to resolve the information need request.
16	**3**	9.0 BOYDEN DEW POINT VALUES Background: As a part of it ssPMP review process, the NRC staff collected observational dew point data for use in conducting independent ssPMP evaluations similar to AWA's process. The NRC staff independently computed values for storm representative dew point, in-place maximum dew point, and transpositioned maximum dew point. NRC staff reviewed the Perry short list storms for warm-season ssPMP and determined that the controlling PMF may be highly sensitive to the dew point values used, particularly for the Boyden, IA storm. As described in the AWA Audit Report (Section 3c [NRC, 2011b]), the impact of smoothing unadjusted PRISM dew point data may have an impact on PMP estimation. Rather than geographically smoothing 100-yr dew point data, NRC staff performed statistical analysis in-line with AWA's approach on a gauge-by-gauge basis to determine the in-place and	The licensee provided the information requested in the ERR (FENOC, 2015d). As a part of the response, the licensee explained that some additional data processing was conducted to properly account for missing data. The resulting August and September dew point climatology values were presented for the two weather stations indicated in the request and were compared with the values estimated using AWA's dew point climatology maps. As a result of the updated data processing, the gridded values at each gauge increased: • KMGW Aug – from 81.2° F to 81.4° F • (AWA climatology map – 77.5° F) • KMGW Sep – from 75.8° F to 76.5° F • (AWA climatology map – 74.7° F) • KAGC Aug – from 77.9° F to 78.8° F • (AWA climatology map – 77.3 F) • KAGC Sep – from 73.9° F to 74.2° F • (AWA climatology map – 74.4° F)

Information Need No.	Reference No./ Transmittal Date[1]	Information Need Description	Response Summary
		transpositioned maximum dew point. After evaluation, NRC staff concluded that: 1. The transpositioned maximum dew point for the Boyden, IA storm may be more conservatively estimated as 78.0° F, compared to the licensee's value of 76.5° F. When combined with other observational data, the above difference in transpositioned maximum dew point values resulted in a total adjustment factor that is approximately 7.6% higher than computed by the licensee, contributing to DAD values in excess of the reported DAD values used by the licensee. Request: Provide the technical basis for selecting a transpositioned maximum dew point value of 76.5° F for the Boyden, IA storm. For the verification of dew point climatology values, the licensee should also submit electronic copies of the dew point climatology calculation sheets for two assigned stations that are near the transpositioned Boyden dew point location (39.43° N, 79.86° W) for the Perry site.	During a telecom held on February 26, 2016, the licensee detailed the process involved in evaluating dew point climatology values for individual gauge stations and acknowledged the increase in dew point values for the two gauges requested for the Boyden, IA storm. Regarding the smoothed map approach, the licensee explained that this approach was followed in the National Oceanic and Atmospheric Administration (NOAA) Sunshine Atlas and that gauge-based values are both higher and lower than the mapped values. The staff continued to have technical concerns after the telecom regarding 1) the possibility of a systematic data processing error by the licensee leading to underestimated dew point climatology maps, and thus non-conservative, low PMP values and 2) the use of smoothed, map-based dew point climatology values which may not adequately capture climatology at local scales. Therefore, the staff performed a sensitivity analysis using the AWA ssPMP and generated a staff-derived ssPMP. The NRC staff reviewed the licensee's response and with the addition of the staff's sensitivity analysis, the staff determined the information provided by the licensee was sufficient to resolve the information need request.
17	4	10.0 COLLEGE HILL DEW POINT VALUES Background: As a part of its ssPMP review process, the NRC staff has collected observational dew point data for use in conducting independent ssPMP evaluations similar to AWA's process. The	The licensee provided the information requested in the ERR (FENOC, 2015d). As a part of the response, the licensee explained that some additional data processing was conducted to properly account for missing data. The resulting June dew point climatology values were presented

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		NRC staff independently computed values for storm representative dew point, in-place maximum dew point, and transpositioned maximum dew point. The NRC staff reviewed the Perry short list storms for warm-season ssPMP and determined that the controlling PMF may be highly sensitive to the dew point values used, particularly for the College Hill, OH storm. As described in the AWA Audit Report (Section 3c [NRC, 2015b]), the impact of smoothing unadjusted PRISM dew point data may have an impact on PMP estimation. Rather than geographically smoothing 100-yr dew point data, the NRC staff performed statistical analysis in-line with AWA's approach on a gauge-by-gauge basis to determine the in-place and transpositioned maximum dew point. After evaluation, NRC staff concluded that: 1. The transpositioned maximum dew point for the College Hill, OH storm may be more conservatively estimated as 78.0° F, compared to the licensee's value of 75.5° F. When combined with other observational data, the above difference in transpositioned maximum dew point values results in a total adjustment factor that is approximately 6.2% higher than computed by the licensee, contributing to DAD values in excess of the reported DAD values used by the licensee.	for the two weather stations indicated in the request and were compared with the values estimated using AWA's dew point climatology maps. As a result of the updated data processing, the gridded values at each gauge increased: • KMFD Jun – from 75.6 ° F to 78.4° F (AWA climatology map – 75.7° F) • KFDY Jun – from unanalyzed to 78.2° F (AWA climatology map – 75.9° F) During a telecom held on February 26, 2016, the licensee detailed the process involved in evaluating dew point climatology values for individual gauge stations and acknowledged the increase in dew point values for the KMFD gauge requested for the College Hill, OH storm (KFDY was not evaluated by AWA). Regarding the smoothed map approach, the licensee explained that this approach was followed in the NOAA Sunshine Atlas and that gauge-based values are both higher and lower than the mapped values. The staff continued to have technical concerns after the telecom regarding 1) the possibility of a systematic data processing error by the licensee leading to underestimated dew point climatology maps, and thus non-conservative, low PMP values and 2) the use of smoothed, map-based dew point climatology values which may not adequately capture climatology at local scales. Therefore, the staff performed a sensitivity analysis using the staff's (4° adjustment) scenario ssPMP values.

Information Need No.	Reference No./ Transmittal Date[1]	Information Need Description	Response Summary
		Request: Provide the technical basis for selecting a transpositioned maximum dew point value of 75.5° F for the College Hill, OH storm. For the verification of dew point climatology values, the licensee should also submit electronic copies of the dew point climatology calculation sheets for two assigned stations that are near the transpositioned College Hill dew point location (40.88° N, 82.47° W) for the Perry Nuclear Power Plant: • MANSFIELD LAHM RGNL (KMFD, WBAN: 14891) • FINDLAY AIRPORT (KFDY, WBAN: 14825) The dew point climatology calculation sheets should cover 1) calculation of June dew point climatology, 2) annual maximum June dew point samples that were used for statistical fitting, 3) fitted generalized extreme value (GEV) distribution parameters, 4) goodness-of-fit measure, and 5) estimated 100-yr dew point values.	The NRC staff reviewed the licensee's response and with the addition of the staff's sensitivity analysis, the staff determined the information provided by the licensee was sufficient to resolve the information need request.
18	**5**	11.0 INITIAL STORM LONG LIST SCREENING Background: After reviewing the initial storm list developed by the licensee for the all-season ssPMP evaluation, the staff noticed that one storm was removed without clear justification. As a result, further clarification is required. The screening criteria used to exclude this storm should be clearly justified.	The licensee explained that the Simpson, KY storm was originally excluded from the list due to it not being transpositionable to Perry (FENOC, 2015d). The AWA stated that the storm was influenced by the topography of the Appalachians, an impact which could not occur at Perry. The licensee also stated that this storm was further investigated as a part of the TVA PMP study, and the effect of topography was confirmed.

Information Need No.	Reference No./ Transmittal Date[1]	Information Need Description	Response Summary
		1. Simpson, KY – July 1939 storm occurring in Kentucky, with a 6-h, 10-mi^2 rainfall of 20.0 inches (according to the Initial Storm Long List). This storm is listed as being removed due to no being "transpositionable to Perry". Request: Provide further justification for the removal of the above storm. If corrections are warranted, provide updated envelopment curves, and, if needed, updated flooding simulations.	The staff found that the terrain surrounding the storm center location is approximately 1200', compared to Perry at 600'. Since this difference in elevation is only 600' (less than the 1000' threshold generally used by AWA for screening), it was not clear to the staff why terrain was found to be a factor. During the telecom held on February 26, 2016, the licensee explained that additional documentation in the ERR supports the reason for assuming topographic influence for the Simpson, KY storm and maintained that the storm is not transpositionable to Perry. The NRC staff notes that if the Simpson, KY storm was considered transpositionable to Perry, it would bound the current ssPMP value at 1-h, 1-mi^2 if assuming the HMR ratio for converting 6-h, 10-mi^2 to 1-hour, 1-mi^2 PMP holds. The licensee suggested that in every case in which this ratio has been explicitly evaluated by AWA, the HMR-based ratio has been found to be very conservative. Based on the NRC staff's review of the licensee's response and the licensee's documentation in the ERR, the staff determined the information provided was sufficient to resolve the information need request.
19	**6**	12.0 WARM-SEASON STORM LIST Background: In addition to reviewing the Initial Storm Long List provided for the Perry ssPMP evaluation, the staff reviewed historical storm event data contained in the USACE "Black Book". Two warm-season storms were identified as being significant enough to warrant consideration in the warm-season ssPMP evaluation in the licensee's	The licensee explained that Perry is outside the transposition limits for the Hallett, OK storm (FENOC, 2015d). The licensee explained that Perry is just within the longitudinal transposition limits for the Stanton, NE storm. Further, the licensee suggests that the storm center location (elevation: 1700') is just above the 1000'-threshold for transposition to Perry (elevation: 600'). Due to the storm being nearly transpositionable to Perry, the licensee further

Information Need No.	Reference No./ Transmittal Date[1]	Information Need Description	Response Summary
		ssPMP, and as a result, further clarification is required. 1. Hallett, OK – September 1940 storm occurring in Oklahoma, with a 6-h, 1-mi^2 DAD value of 18.9 inches. This storm is listed as SW 2-18 in the USACE Black Book. 2. Stanton, NE – June 1944 storm occurring in Nebraska, with a 6-h, 1-mi^2 DAD value of 15.5 inches. This storm is listed as MR 6-15 in the USACE Black Book. Request: Provide an explanation for why the above warm-season storms were not included in the Initial Storm Long List. If the storm is considered transpositionable to the Perry watershed and corrections are warranted, provide updated storm calculation and envelopment curves, and, if needed, updated flooding simulations.	evaluated the Stanton, NE storm. The licensee found that the total adjustment factor of the storm is 1.25 and suggested that the use of this adjustment factor results in a 1-hour, 1-mi^2 value of 11.45", which is below the current site-specific 1-hour, 1-mi^2 PMP of 12.12". Based on the telecom discussion and the staff's review of the licensee's response, the staff determined the information provided was sufficient to resolve the information need request.
20	**1**	**Local Intense Precipitation – Building Structures and Rooftop Water Storage** Background: FHRR Section 3.8.3 indicated that the licensee added a levee system around the perimeter of the buildings to represent the building parapets (FENOC, 2016a). The staff examined the water stored at the rooftop of the buildings and found that up to approximately a foot of water was stored in grid cells representing the rooftops of some of the buildings. In accordance with Section 11.4 of ANSI/ANS 2.8 -1992 (ANS, 1992), runoff	During the audit telecom on June 21, 2016, the licensee explained that runoff from the building rooftops is removed in the FLO-2D model through either the roof drainage system or direct routing to the ground surface. For the buildings that have the parapet wall as part of the building structure, the licensee added the levee system around the building perimeter to represent the actual roof conditions. The licensee further indicated that the buildings at the PERRY are structurally safe to hold a foot of water on the roof. No levee was added to a building perimeter that does not currently have parapet wall.

Information Need No.	Reference No./ Transmittal Date[1]	Information Need Description	Response Summary
		from the building rooftops should be routed to the surrounding ground surface, but the levee system did not allow the runoff to route directly from the rooftops. Request: Provide the justification of adding the levee around the building perimeters in the model, which allows more water storage on the rooftops during the LIP event, or revise the model in accordance with Section 11.4 of ANSI/ANS 2.8 - 1992 (ANS, 1992).	The staff reviewed the licensee's model and response to the information need request, the staff concluded that the licensee's response was sufficient to address the information need request.
21	2	**Local Intense Precipitation – Modeling of storm drain system network** Background: The FHRR Section 3.8.3 LIP analysis incorporated flow routing through the storm drain, underdrain, and roof drain systems using the Environmental Protection Agency's Storm Water Management Model (SWMM) (EPA, 2011) computer software, which was integrated with the site FLO-2D model. As stated in NUREG/CR-7046 (NRC, 2011) regarding the Design-Basis Flood Estimation, the most conservative approach would consider the active drainage system non-functional and the passive drainage network compromised at the time of LIP flooding analysis. Request: Provide the justification for allowing the storm drain (50% area reduction, 25% perimeter reduction, and 10% pipe capacity reduction), underdrain (no reduction), and roof drain system (no	The licensee confirmed, during the telecom on June 21, 2016, that the drainage system represented by the SWMM model was integrated in the FLO-2D model and the partial reduction is reasonable based on the actual drainage systems that convey water away from the power block. The NRC staff concluded that the licensee's response was sufficient to address the information need request.

Information Need No.	Reference No./ Transmittal Date[1]	Information Need Description	Response Summary
		reduction) networks to be active during the LIP event by integrating SWMM into the FLO-2D model. Discuss the conservativeness of this approach.	
22	3	**Ice-Induced Flooding – Major Stream** Background: For the Major Stream, the FHRR Section 3.3.4 considered ice at the railroad bridge blocking flow to the stated depth, then overtopping (FENOC, 2016a). Request: Is it plausible that the ice jam could fail, resulting in a much larger volume of water moving through the ice jam in a much shorter amount of time (ice jam break)? If so, please provide discharge and related elevation of impact at the site.	The licensee explained that the ice jam analysis has been done to look at the flooding caused by the upstream ice jam failure (similar to dam failure), and backwater due to the downstream ice jam blockage. The licensee confirmed that the ice-jam failure at the railroad bridge is bounded by the PMF (FENOC, 2016c). The staff performed a calculation that quantified the flooding due to the failure of an 18 ft. deep ice jam upstream of the railroad bridge. Based on the licensee's response and the staff's calculation, the NRC staff concluded that no further information is required to address the information need request.
23	4	**Ice-Induced Flooding – Minor Stream** Background: For the Minor Stream, FHRR Section 3.3.4 presented ice jam at a culvert under Lockwood Road. The ice jam flow that was considered consists only of that overtopping the road (FENOC, 2016a). Request: Is it plausible that the culvert could clear [the] ice and add pressure flow through the culvert coincident with overtopping? If so, please provide discharge and related elevation of impact at the site.	The licensee stated (FENOC, 2016c) that the potential ice-jam location at Lockwood Road on the Minor Stream is confirmed near the lake downstream of the power block and that the only impact on the power block area would be the backwater effect. The licensee stated that the resulting WSE is significantly lower than the PMF elevation. The NRC staff concluded that the information provided by the licensee was sufficient to address the information need request.

Information Need No.	Reference No./ Transmittal Date[1]	Information Need Description	Response Summary
24	Clarification 1	**<u>Streams and Rivers Flooding – Model input/output files</u>** <u>Background</u>: The licensee made some topographical changes, among others, at the site that resulted in updates to the model input/output files for HEC-HMS and HEC-RAS. The licensee made these updated model input/output files available to the staff via external hard drives and incorporated a summary of the analysis and results as part of Revision 1 to the FHRR (FENOC, 2016a). The updated model files were not incorporated by reference in the FHRR, Revision 1, and these models were not submitted on the docket to supplement the revision of the flooding analysis and report. <u>Request</u>: The staff requests that the model input/output files that correspond to the model files used as the basis for the FHRR Revision 1 results provided on the docket.	The licensee provided the requested input/output files for review on November 9, 2016 (FENOC, 2016c). The NRC staff concluded that the information provided by the licensee was sufficient to address the information need request.
25	Clarification 2	**<u>Streams and Rivers Flooding – Diversion channel flow</u>** <u>Background</u>: The FHRR states that the peak flow of the PMF inflow hydrograph for the Diversion Channel (Re-aligned Channel) is 4,200 cfs (FENOC, 2016a). However, the HMS model output and RAS model input show that the inflow hydrograph for the Diversion Channel has a peak flow of about 4,600 cfs (FENOC, 2016b).	The licensee confirmed that the peak flow (4,600 cfs) of the PMF computed from the HEC-HMS model was applied as inflow to the HEC-RAS model without modification. The flow of 4,200 cfs is the routed peak flow at the upper stream cross section as an output of the HEC-RAS model (FENOC, 2016d).

Information Need No.	Reference No./ Transmittal Date[1]	Information Need Description	Response Summary
		Request: Please confirm the peak flow of 4,200 cfs and provide a source; or, correct the value presented in the FHRR.	The NRC staff concluded that the information provided by the licensee was sufficient to address the information need request.
26	Clarification 3	**Streams and Rivers Flooding – Access Road height modification** Background: The FHRR states in Section 3.1.4 that the Secondary Access Road was raised to exceed the maximum water surface elevation of 631.4 ft. Perry Local Datum as part of the modifications performed in 2015, but the final as-built elevations along the raised Access Road were not described in the FHRR (FENOC, 2016a). Request: Provide the final as-built surveyed elevations and coordinates along the raised Secondary Access Road.	In response to this clarification request, the licensee provided as-built survey data file and drawing in the ERR, which indicated the Secondary Access Road has been raised and the final elevations along road crest exceeds the maximum water surface elevations computed in the FHRR. The Secondary Access Road after the latest modification prevents the flows from the Major Stream to the north toward the power block area and to the east toward the Diversion Channel (FENOC, 2016e). The NRC staff concluded that the information provided by the licensee was sufficient to address the information need request.

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