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

December 14, 2016

Mr. Brian D. Boles
FirstEnergy Nuclear Operating
Company
c/o Davis-Besse NPS
5501 N. State Route 2
Oak Harbor, OH 43449-9760

SUBJECT: DAVIS-BESSE NUCLEAR POWER STATION, UNIT 1 – STAFF ASSESSMENT OF RESPONSE TO 10 CFR 50.54(f) INFORMATION REQUEST – FLOOD-CAUSING MECHANISM REEVALUATION (CAC NO. MF3721)

Dear Mr. Boles:

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 11, 2014 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML14070A108), FirstEnergy Nuclear Operating Company (FENOC, the licensee) responded to this request for Davis-Besse Nuclear Power Station, Unit 1.

By letter dated September 3, 2015 (ADAMS Accession No. ML15239B212), the NRC staff sent FENOC a summary of the staff's review of the licensee's reevaluated flood-causing mechanisms. The enclosed staff assessment provides the documentation supporting the NRC staff's conclusions summarized in the letter. As stated in the letter, the reevaluated flood hazard result for local intense precipitation and storm surge were not bounded by the current design-basis flood hazard. 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 evaluates and implements any necessary programmatic, procedural, or plant modifications to address this hazard exceedance. Additionally, for the storm surge flood-causing mechanism, the NRC staff anticipates that the licensee will submit (1) a focused evaluation confirming the capability of existing flood protection or describing new flood protection capabilities for this mechanism or (2) an integrated assessment.

This closes out the NRC's efforts associated with CAC No. MF3721.

If you have any questions, please contact me at (301) 415-3809 or e-mail at Juan.Uribe@nrc.gov.

Sincerely,

Juan Uribe, Project Manager
Hazards Management Branch
Japan Lessons-Learned Division
Office of Nuclear reactor Regulation

Docket No. 50-346

Enclosure:
Staff Assessment of Flood Hazard
Reevaluation Report

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STAFF ASSESSMENT BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATED TO FLOODING HAZARD REEVALUATION REPORT

NEAR-TERM TASK FORCE RECOMMENDATION 2.1

DAVIS-BESSE NUCLEAR POWER STATION, UNIT 1

DOCKET NO. 50-346

1.0 INTRODUCTION

By letter dated March 12, 2012 (NRC, 2012a), the U.S. Nuclear Regulatory Commission (NRC) issued a request for information to all power reactor licensees and holders of construction permits in active or deferred status, pursuant to Title 10 of the *Code of Federal Regulations* (10 CFR), Section 50.54(f), "Conditions of Licenses" (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 NRC's Near-Term Task Force (NTTF) report (NRC, 2011a). Recommendation 2.1 in that document recommended that the staff issue orders to all licensees to reevaluate seismic and flooding for their sites against current NRC requirements and guidance. Subsequent staff requirements memoranda associated with SECY-11-0124 (NRC, 2011b) and SECY-11-0137 (NRC, 2011c) directed the NRC staff to issue requests for information to licensees pursuant to 10 CFR 50.54(f) to address this recommendation.

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

By letter dated March 11, 2014 (FENOC, 2014a), FirstEnergy Nuclear Operating Company (FENOC, the licensee) provided its FHRR for Davis-Besse Nuclear Power Station, Unit 1 (Davis-Besse). In a second letter dated July 17, 2014 (FENOC, 2014b), the licensee provided additional information related to its FHRR. In October 2014, the licensee identified a software error in the FLO-2D computer code used to model flooding due to local intense precipitation (LIP). In light of this vendor error, the licensee performed new LIP flood hazard calculations and provided those corrected calculations to the NRC staff in a third letter dated February 25, 2015 (FENOC, 2015c).

On September 3, 2015, the NRC issued an interim staff response (ISR) letter to the licensee (NRC, 2015b). The purpose of the ISR letter was to provide the flood hazard information suitable for the assessment of mitigating strategies developed in response to Order EA-12-049, "Requirements for Mitigation Strategies for Beyond-Design-Basis External Events" (NRC, 2012b) and the additional assessments associated with NTTF Recommendation 2.1: Flooding.

The ISR letter also made reference to this staff assessment, which documents the NRC staff's basis and conclusions. The flood hazard mechanism values presented in the letter's enclosures match the values in this staff assessment without change or alteration.

As mentioned in the ISR letter and discussed below, the reevaluated flood hazard results for the LIP and storm surge flood-causing mechanisms are not bounded by the plant's current design basis (CDB) hazard. Consistent with the 50.54(f) letter and amended by the process outlined in COMSECY-15-0019 and Japan Lessons Learned Division (JLD) Interim Staff Guidance (ISG) JLD-ISG-2016-01, Revision 0 (NRC, 2015b; NRC, 2016b), the staff anticipates that for LIP, the licensee will perform and document a focused evaluation to assess 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 storm surge flood-causing mechanism, the staff anticipates that the licensee will submit (a) a revised integrated assessment or (b) a focused evaluation 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, 2016b).

Additionally, for any reevaluated flood hazards that are not bounded by the plant's CDB hazard, the licensee is expected to develop any flood event duration (FED) and associated effects (AE) parameters that have not been provided in order to conduct the mitigating strategies assessment (MSA) and focused evaluations or revised integrated assessments, as discussed in Appendix G of NEI-12-06, Revision 2 (NEI, 2015b); JLD-ISG-2012-01, Revision 1 (NRC, 2016a); JLD-ISG-2012-05 (NRC, 2012d); and JLD-ISG-2016-01, Revision 0 (NRC, 2016b); respectively.

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 facility site with a particular emphasis on the site evaluation factors identified in 10 CFR Part 100. The licensee should provide any pertinent information identified or developed since the submittal of the preliminary safety analysis report in the final safety analysis report.

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

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

Section 54.3 of 10 CFR defines the "current licensing basis" (CLB) as "the set of NRC requirements applicable to a specific plant and a licensee's written commitments for ensuring compliance with and operation within applicable NRC requirements and the plant-specific design basis (including all modifications and additions to such commitments over the life of the license) that are docketed and in effect".

This includes 10 CFR Parts 2,19, 20, 21, 26, 30, 40, 50, 51, 52, 54, 55, 70, 72, 73, 100 and appendices thereto; orders; license conditions; exemptions; and technical specifications, as well as the plant-specific design-basis information as documented in the most recent final safety analysis report. The licensee's commitments made in docketed licensing correspondence that 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 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, that enable the Commission to determine whether or not the license should be modified, suspended, or revoked. The 50.54(f) letter (NRC, 2012a) requested that all power reactor licensees and construction permit holders reevaluate all external flooding-causing mechanisms at each site. This includes applying current techniques, software, and methods used in present-day standard engineering practice.

2.2.1 Flood-Causing Mechanisms

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 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. The licensee should incorporate and report associated effects per JLD-ISG-2012-05, "Guidance for Performing the Integrated Assessment for External Flooding" (NRC, 2012c), in addition to the maximum water level associated with each flood-causing mechanism.

2.2.2 Associated Effects

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

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

2.2.3 Combined 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." 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," also referred to as "combined events," 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 licensee should document and report the result as part of one of the hazard sections. An example of a situation where this may occur is flooding at a riverine site located where the river enters the ocean. For this site, storm surge and river flooding should be plausibly combined.

2.2.4 Flood Event Duration

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

2.2.5 Actions Following the FHRR

For the sites where the reevaluated flood hazard is not bounded by the CDB flood hazard for all flood-causing mechanisms, the 50.54(f) letter (NRC, 2012a) requests licensees and construction permit holders to:

- Submit an interim action plan with the FHRR documenting actions planned or already taken to address the reevaluated hazard.
- 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. Guidance document COMSECY-15-0019 and JLD-ISG-2016-01, Revision 0, outline a revised process for addressing cases in which the reevaluated flood hazard is not bounded by the plant's CDB (NRC, 2015c and NRC, 2016c). 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 that assesses the impact of the LIP hazard on their sites and then evaluates and implements any necessary programmatic, procedural, or plant modifications to address this hazard exceedance. For other 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 an integrated assessment (NRC, 2015a and NRC, 2016c).

3.0 TECHNICAL EVALUATION

The NRC staff reviewed the information provided for the flood hazard reevaluation of the Davis-Besse site. The licensee conducted the hazard reevaluation using present-day methodologies and regulatory guidance used by the NRC staff in connection with ESP and COL reviews.

To provide additional information in support of the summaries and conclusions in the FHRR, the licensee made calculation packages available to the staff via an electronic reading room. When the staff relied directly on some of these calculation packages in its review, they or portions thereof were docketed. Certain other calculation packages were found only to expand upon and clarify the information provided on the docket, and so are not docketed or cited. The staff's review and evaluation is provided below.

Finally, some licensee documents were reviewed in connection with the staff's August 2015 audit of the Davis-Besse FHRR. Many of those documents were also not requested to be docketed from the licensee. The documents reviewed by the staff as part the audit were cited in the July 2016 audit summary report (NRC, 2016b) prepared by the NRC staff.

3.1 Site Information

The 50.54(f) letter includes the SSCs important to safety in the scope of the hazard reevaluation. Specifically, Enclosure 2 of the 50.54(f) letter describes site information to be contained in the FHRR. The licensee included pertinent data concerning these SSCs in the FHRR (FENOC, 2014).

3.1.1 Detailed Site Information

The nominal grade of the Davis-Besse site is elevation 584 feet (ft) (178 m) International Great Lakes Datum of 1955 (IGLD55). In general, most of the elevations in this staff assessment are reported as IGLD55. However, there are a few elevations reported in terms of the North American Vertical Datum of 1988 (NAVD88). At the Davis-Besse site, the conversion between IGLD55 and the NAVD88 is IGLD55 = NAVD88 -1.1 ft (0.3 m). Ground surface elevations at the reactor site are generally uniform, based on the use of compacted fill to elevate the footprint of the powerblock yard prior to construction (FENOC, 2014). The finished floor elevation of Unit 1 and other safety-related structures within the powerblock footprint is 585 ft (178.3 m) IGLD55. Structures designated seismic Category I are designed to withstand a static water level of 584.0 ft

(178.0 m) IGLD55. The auxiliary building and containment vessel were reported to have no access openings below elevation 585.0 ft (178.3 m) IGLD55. The licensee reported that it relies on a variety of flood protection measures for various structures at lower elevations (below grade), in order to provide additional protection against flooding effects. Those measures include waterproofing, covered or sealed penetrations, water stops, floor drains, and sumps. The powerblock yard is designed to collect site runoff, as well as roof drainage, and route the effluent to the Toussaint River, located south of the site. This river ultimately discharges into nearby Lake Erie.

The Davis-Besse site is located on the southwestern shore of Lake Erie, the principal hydrologic feature of interest, on a relatively flat plain underlain by glacial deposits. These deposits are approximately 20 ft (6.1 m) thick, and the flat plain dips gently to the east towards Lake Erie. Several fresh water marshes are located between the reactor site and Lake Erie, including the Navarre Marsh section of the Ottawa National Wildlife Refuge. Those marshes are located to the southeast of the site and represent flooded areas of wetland vegetation. The Davis-Besse site consists of 954 acres (386 hectare) of which approximately 733 acres (297 hectare) are marshland. The probable maximum stillwater level for Lake Erie is about 573 ft (174 m) IGLD85; the mean stillwater level is about 570 ft (173.7 m) IGLD55. The water elevation in the marshes is generally consistent with Lake Erie water levels, except when the licensee operates pumps to control the water level on behalf of the U.S. Fish and Wildlife Service. The marshes are separated from Lake Erie by a series of wave protection dikes and a narrow barrier beach along the shoreline. The crest elevation of the wave protection dike is 591 ft (180.1 m) IGLD55.

All surface (meteoric) water is passively removed off of the site using a system of storm drains and ditches that discharge either into one of the marsh areas or the Toussaint River, to the south of the reactor site. There are two canals associated with the operation of the Davis-Besse site. The first is an intake canal that connects to Lake Erie and provides the site with make-up water for: the circulating water system, the service water system, and the fire protection system. The forebay for this canal is adjacent to the intake structure and is designed for the probable maximum flood (PMF). To protect against wave run-up related meteorological phenomena associated with Lake Erie, the area around the station is protected along the north, east, and partially along the south by an earthen wall or breakwater built to an elevation of 591.0 ft (180.1 m) IGLD55. The front wall of the intake structure is designed to withstand hydrodynamic forces associated with the maximum probable hydrodynamic water level (i.e., run-up). At the shoreline, there is an underwater intake pipe that extends an additional 3,000 ft (914.4 m) into Lake Erie; the submerged pipe was installed below the lake bed. A second canal runs between the turbine building and the reactor's cooling tower.

A flood control dike (consisting of earthen rip-rap) has also been constructed around the north-, east-, and a portion of the south-facing sides of the reactor site to an elevation of 591 ft (180.1 m) IGLD55. This flood control dike extends circumferentially around the intake canal and also has a crest elevation of 591 ft (180.1 m) IGLD55. Figure 3.1-1 depicts key features of the Davis-Besse reactor site described in this staff assessment.

Approximately 2,000 ft (609.6 m) to the south of the Davis-Besse site is the Toussaint River, the other principal hydrologic feature of interest near the reactor complex. This west-to-east flowing waterway is about 37 miles (mi) (59.5 km) long and has a drainage area of about 143 square miles (mi^2) (370.4 km^2), mostly to the west of the site (State of Ohio, 2006). At a location to the west of the reactor site, the river transitions into two creeks. The licensee reported that the Toussaint River transitions into a creek, approximately 6 mi upstream from its mouth at Lake Erie (Sena, 2012). The river ultimately discharges into a shallow marsh area contiguous with Lake Erie to the south of the reactor site. A narrow strip of marshland separates the Toussaint River from the Davis-Besse site. No dams or other impoundments are reported in connection with the Toussaint River; the river is also not gauged. The nominal elevation of the river is controlled by the corresponding water level within Lake Erie. The licensee reported that no water is removed from the Toussaint River to meet reactor cooling needs.

Groundwater intrusion is not considered to be a design issue; the glacial till deposits have historically reported to be deficient in groundwater (Environmental Resources Management, 2007). However, some groundwater has been reported in the dolomite bedrock underlying the surficial glacial deposits at depths greater than 20 ft (6.1 m) below the ground surface, and flow there is reported to be controlled by secondary depositional features.

3.1.2 Design-Basis Flood Hazards

The CDB flood levels for the Davis-Besse site are discussed in the FHRR (FENOC, 2014) and summarized by flood-causing mechanism in Table 3.1-1. Design-basis flooding hazards at the site include: storm surge-related flooding associated with Lake Erie, LIP, and flooding on the Toussaint River.

Flooding attributed to storm surge on Lake Erie resulted in a probable maximum water level of 583.7 ft (177.9 m) IGLD55. Maximum wave run-up was calculated to be 6.6 ft (2.0 m) above the probable maximum stillwater level, resulting in a total maximum elevation of 590.3 ft (179.9 m) IGLD55.

The licensee's LIP analysis estimates a theoretical water buildup of 584.5 ft (178.2 m) IGLD55 which accounts for surface drainage offsite to surrounding areas ranging in elevation from 570.0 to 575 ft (173.7 to 175.3 m) IGLD55. Local intense precipitation with a duration of up to one hour is the only time-dependent flooding hazard considered in the Davis-Besse licensing basis. Although the Toussaint River is within the licensing basis, it's not considered to be a likely flood hazard because of its relatively small catchment area; its unfettered connection to Lake Erie, which controls the water surface elevation (WSE) within the river; and the fact that the river is relatively wide in the vicinity of the power plant site. Using the probable maximum rainfall in the Toussaint River drainage area, the maximum WSE at the site was estimated at 579 ft (176.5 m) IGLD55.

The licensee noted that the Davis-Besse site is not considered to be susceptible to flooding as a result of dam failures, ice jams, channel migration, tsunami, tidal surge, or seiche effects. As a consequence, these flooding scenarios were not considered as part of the original licensing basis. The staff reviewed the information provided in the FHRR and determined that sufficient information was provided to be responsive to Enclosure 2 of the 50.54(f) letter.

3.1.3 Flood-Related Changes to the Licensing Basis

The licensee reported that there was no information to suggest that anthropogenic factors have had an impact on the watersheds encompassing the Davis-Besse site. The licensee also stated (FENOC, 2014) that recent modifications to the Davis-Besse site were limited to certain buildings, facilities, and parking lots to accommodate the steam generator replacement project.

The licensee noted that these changes were accounted for in the hydrologic models used in the FHRR though the use of improved, higher-resolution topographic data for the region and site. The staff reviewed the information provided in the FHRR and determined that sufficient information was provided to be responsive to Enclosure 2 of the 50.54(f) letter.

3.1.4 Changes to the Watershed and Local Area

Changes reported by the licensee for the watershed encompassing the Davis-Besse site included some limited development within the watershed. Those changes include some commercial development outside of the power station controlled area, as well as some additions within the controlled area itself. Changes within the controlled area are in the form of new buildings, parking lots, and improvements to site security barriers. These changes were accounted for in the applicable Davis-Besse FHRR analyses performed by the licensee.

3.1.5 Current Licensing Basis Flood Protection and Pertinent Flood Mitigation Features

The CLB flood protection level is 585 ft (178.3 m) IGLD55, which corresponds to the finished floor elevation of powerblock structures. In general, those structures were constructed 6 ft to 14 ft (1.8 m to 4.3 m) above the existing site grade to an elevation of 584 ft (178.0 m) IGLD55 to provide protection from Lake Erie's maximum credible flood level condition. To protect against wave run-up associated with Lake Erie flooding, the area around the station is protected along the north, east, and partially along the south by an earthen breakwater; the top of this structure is elevation 591.0 ft (180.1 m) IGLD55. The front wall of the intake structure facing in the direction of Lake Erie is designed to withstand hydrodynamic forces associated with the maximum probable hydrodynamic run-up level from that waterbody.

Seismic Category I structures at the reactor site are designed to withstand a static water level of 584.0 ft (178.0 m) IGLD55. A variety of flood protection measures are employed at elevations below the static water level for the various structures. Those measure include waterproofing, covered or sealed penetrations, water stops, floor drains, and sumps. The station's drainage system is designed to collect site runoff in addition to roof drainage and route the effluent to ditches draining into the Toussaint River. A service water tunnel and associated rooms are also reported to utilize waterproof membranes for flood protection (Sena, 2012).

Adverse weather conditions were considered, and include a probable maximum meteorological event in connection with storm surge to determine water rise in Lake Erie due to sustained wind setup. The resulting maximum wind speed considered was 100 miles per hour (161 km per hour) over a 10 minute period.

The site has incorporated exterior barriers that are permanently in-place, requiring no operator manual actions. These barriers include mitigation measures, such as waterproof envelope systems for building, construction joint water stops, sump pumps, flood doors, floor drains, and watertight doors. There are also the aforementioned earthen dikes intended to provide wave run-up protection. The majority of the walls and floors are credited to protect equipment from groundwater intrusion.

The site requires no temporary barriers or flood protection equipment that requires operator action. The staff reviewed the information provided in the FHRR and determined that sufficient information was provided to be responsive to Enclosure 2 of the 50.54(f) letter.

3.1.6 Additional Site Details to Assess the Flood Hazard

The licensee reported that an aerial survey had been conducted as part of the FHRR in order to obtain both newer and improved topographic data compared to that which was available at the time that previous flood hazard evaluations had been prepared for the Davis-Besse site. Those earlier evaluations were prepared in connection with the Individual Plant Evaluation of External Events (IPEEE) and took place in the late 1980s to early 1990s. Higher-resolution, digital terrain data were generally not available until after the IPEEE program had been completed. The newer, higher-resolution data used in the FHRR improved delineation of watershed boundaries and other hydrologic features of interest.

3.1.7 Results of Plant Walkdown Activities

The 50.54(f) letter (NRC, 2012a) requested that licensees 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 submitted a flooding walkdown report as requested in Enclosure 4 of the 50.54(f) letter for the Davis-Besse site. By letter dated January 30, 2014, FENOC provided a response to the NRC request for additional information for the staff to complete its staff assessment. On May 20, 2014 (NRC, 2014), the 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 walkdown guidance.

3.2 Local Intense Precipitation and Associated Site Drainage

The licensee reported that the reevaluated flood hazard, including associated effects, for LIP and associated site drainage is based on a stillwater WSE of 585.5 ft (178.46 m) IGLD55. The licensee stated that wind waves and run-up had no effect on the LIP flood elevations and thus were not considered as part of the CDB (FENOC, 2014). This flood-causing mechanism is discussed in the licensee's CDB. The CDB PMF elevations for LIP and associated site drainage are based on stillwater-surface elevations of 584.5 ft (178.16 m) IGLD55 (FENOC, 2014).

3.2.1 Site Drainage and Elevations

The licensee reevaluated the flood hazard resulting from LIP due to a thunderstorm over an immediate drainage area of about 0.3 mi^2 (0.8 km^2) that included the footprint of the Davis-Besse powerblock, the site's vehicle barrier system (VBS), and all contiguous natural drainage areas in the 1.49 mi^2 (3.86 km^2) controlled area. The licensee reevaluated the flood hazard due to LIP using a digital terrain model (DTM) to approximate the topographic ground surface corresponding to the reactor site and environs. Because the finished grade of the powerblock is elevated relative to the surrounding topography, the licensee generally did not include lower-elevation areas in its computational model as meteoric water would be expected to drain off-site via gravity as suggested by the results of the computer simulation shown on Figure 3.2-1.

The licensee selected a 10-ft^2 (3.0-m^2) resolution for the FLO-2D computational grid. The licensee further noted that the size of the grid cells was small enough to capture important site details within the powerblock and yet sufficient in size to ensure computational stability, such as reasonable computational output values and minimal errors. The licensee noted that it evaluated alternative grid cell dimensions to understand the sensitivity of the LIP model to grid size. A larger 15-ft^2 (4.6-m^2) grid was evaluated and found to cause numerical surging in the estimated WSE results. A smaller 5-ft^2 (1.5-m^2) grid was also evaluated and found to produce maximum WSEs that varied by ±0.2 ft (±0.07 m) for 90 percent of the cells within in the computational domain, excluding outliers (FENOC, 2014b).

The staff reviewed the licensee's approach to the development of the computation grid for the FLO-2D model against relevant regulatory criteria based on present day methodologies and regulatory guidance. The staff considers that the approach described by the licensee is reasonable.

3.2.2 Local Intense Precipitation

The licensee selected a 1-hour (1-hr), 1-mi^2 (2.6 km^2) probable maximum precipitation (PMP) event for the purposes of the LIP analysis. The magnitude of the PMP event was estimated using the National Weather Service's Hydrometeorological Reports (HMRs) 51 and 52 applicable to the site. Using those two references, the magnitude of the 1-hr, 1-mi^2 (2.6 km^2) PMP event selected for the Davis-Besse site was estimated as 17.3 in (43.9 cm) based on a PMP depth contour map contained in HMR 51 (Schreiner and Reidel, 1978). The licensee noted that it had obtained the distribution of the 1-h PMP for the 5-, 15-, 30-, and 60-minute time intervals from HMR 52 (Hansen, Schreiner, and Miller, 1982). When considering the front-weighted rainfall distribution, approximately 30 percent of the precipitation typically occurs during the first 5 minutes of the storm event. The licensee also considered the one-third hour, central, two-thirds hour, and end-loaded temporal distributions. During the July 2015 audit, the licensee noted that the 1-hr, 1-mi^2 (2.6 km^2) PMP event fully envelopes the drainage area that includes the reactor site (NRC, 2016b). The licensee further noted that the effect of LIP-induced flooding at the reactor site was controlled primarily by rainfall intensity rather than rainfall quantity as the site topography is relatively flat. The licensee stated that extending the temporal duration of the rainfall event is likely not to change the maximum WSE as the maximum storm intensity relied on for the purposes of the LIP assessment would still be the same. In connection with this topic, during the July 2015 audit (NRC, 2016b), the licensee determined that the 1-h PMP event temporal distribution used in the calculation is the same as the temporal distribution of the LIP event presented as a case study described in NUREG/CR-7046, Appendix B, Figure B-5 (i.e., a front-loaded precipitation event).

The staff reviewed the licensee's estimation of PMP against relevant regulatory criteria based on present day methodologies and regulatory guidance. The staff considers that the methods presented in the HMRs, as referenced by the licensee, are reasonable methods for estimating those values.

3.2.3 Runoff Analysis

The licensee reevaluated the flood elevation from a LIP event using the FLO-2D Pro computer code to numerically estimate flows and water-surface elevations within a two-dimensional gridded domain that can include channels, hydraulic structures, and flow obstructions.

The location of physical obstructions present within the modeling domain were identified and confirmed using available aerial imagery of the site. Grid elements coinciding with buildings were modeled as obstructions that completely blocked the passage of surface water. The staff determined that the locations of buildings and other structures were properly implemented in the FLO-2D computer model, and that the representation of those features with higher elevations would both promote flow from those cells as well as prevent surface flow into those cells. The licensee's computer model correctly accounted for rooftop runoff by routing flow off cells coinciding to building locations and adding that flux to surface flow occurring in adjacent cells corresponding to the ground surface. The FLO-2D model boundary and other key features of the LIP model are shown in Figure 3.1-1.

One additional building, a new steam generator storage facility, was found to have been constructed within the powerblock footprint subsequent to the topographic survey conducted for the purposes of the FHRR. The licensee noted that the outline of the south side of that structure had been incorrectly represented in an early version of the LIP model, and was later corrected and re-evaluated in a revised LIP calculation described in a calculation package referenced in the FHRR. The licensee also modeled the reactor site's extensive VBS using two types of levee designations in FLO-2D, manipulating the tools available in the computer code to account for different spacing distances between the individual elements of the VBS system. The staff reviewed the manner in which the VBS system was treated within the FLO-2D model and finds it appropriate. Hydraulic losses for the water flow through the openings were not incorporated, which is consistent with the overall conservative approach to maximize WSEs in the site model.

Based on the site topographic information provided by the licensee, the staff found the licensee's use of the outflow boundary conditions for the FLO-2D model appropriate. The staff reviewed the licensee's FLO-2D model and determined that storm water conveyance structures were assumed to be completely blocked, consistent with NUREG/CR-7046 (NRC, 2011). The staff also determined that the location of the VBS was appropriately represented in the model and that the representation of that feature with blocked openings (modeled as a levee) was consistent with NUREG/CR-7046 (NRC, 2011).

During a July 2015 audit (NRC, 2016b), the staff asked the licensee to describe how drainage from facility roofs, as represented in the FLO-2D analyses, is consistent with the guidance in ANSI/ANS-2.8-1992, Section 11.4. This section recommends that building runoff used in LIP flood assessment allow for the evaluation of a worst case roof drainage scenario. In response, the licensee noted that no alternative points of roof drainage scenarios were developed or analyzed in connection with the LIP flood hazard analysis for two reasons. First, the licensee conservatively assumed that all meteoric water falling on Davis-Besse roof structures finds its way to the powerblock yard. Second, in the FLO-2D computer model, the licensee also noted that roof pitch orientations were selected (in the east-west direction) so as to maximize overland runoff volumes in that particular direction – another modeling conservatism given the topography of the site. For these reasons, the licensee again expressed the view that the approach used in its LIP calculation to model roof drainage corresponds to the worst case of roof drainage scenario, as required by ANSI/ANS-2.8-1992, Section 11.4.

The licensee assigned specific Manning's n values (roughness coefficients) to land cover types within the LIP model based primarily on coefficient ranges suggested in the FLO-2D Reference Manual. A parametric sensitivity analysis was performed by the licensee to evaluate the LIP model's sensitivity to the parameter values selected. The upper and lower bounds of the recommended coefficient ranges replaced the estimated n values (water, gravel and herbaceous cover were kept constant) to determine if there were changes in the resulting maximum WSE. The licensee reported that the sensitivity analysis produced WSE depth differences of between 0 and 0.1 ft (0.03 m) within the powerblock area. Those results suggested that the LIP model was not largely dependent on the value of the Manning's roughness coefficient selected. The staff reviewed the Manning's n values selected by the licensee and concluded that the values selected were reasonable. In connection with its review, the staff also reviewed aerial imagery of the Davis-Besse site to confirm that the surface cover was consistent with the Manning's n values selected.

3.2.4 Water Level Determination

The licensee identified 12 potential flooding pathway locations around the turbine building (five locations), the auxiliary building (six locations), and the intake structure by which meteoric flood water could potentially affect plant safety, and reported maximum flood elevation, flooding duration, maximum velocity, maximum flow depth, and maximum hydrostatic and hydrodynamic forces at the locations in question (FENOC, 2015b). Table 3.2-1 describes the maximum WSEs and depth at critical doors of the safety-related buildings for an end-loaded temporal rainfall distribution. The end-loaded precipitation distribution produced the LIP event that resulted in the highest maximum WSE of 585.4 ft (178.4 m) IGLD55 at multiple door locations of the auxiliary building; of 585.5 ft (178.5 m) IGLD55 at Door 334 of the turbine building; and 585.5 ft (178.5 m) IGLD55 at the intake structure location.

The staff performed independent analyses of the results reported in the FHRR by using the computer input files provided by the licensee. The staff reviewed the resulting model output and determined that (a) mass balance errors were small, (b) flow pathways and areas of inundation appeared reasonable, and (c) flow velocities were reasonable with no indication of numerical instabilities and no supercritical flow conditions near the potential flooding pathways identified by the licensee. Based on these results, the staff finds the licensee's revised FLO-2D model (FENOC, 2015c) to be an acceptable basis for evaluating water elevations and associated site drainage due to LIP.

After independently executing the licensee's FLO-2D computer code input files, the staff confirmed the depths and locations of the maximum WSEs reported for each of the three Davis-Besse structures cited in the FHRR. The staff further concluded that the maximum WSEs reported by the licensee were consistent with the estimates calculated by the staff.

3.2.5 Conclusion

The staff confirmed that the licensee's reevaluation of the LIP hazard used present-day methodologies and regulatory guidance. The staff also confirmed the licensee's conclusion that the reevaluated flood hazard for LIP is not bounded by the CDB flood hazard. Therefore, the staff expects that the licensee will submit a focused evaluation consistent with the process and guidance discussed in COMSECY-15-0019 (NRC, 2015a) and JLD-ISG-2016-01, Revision 0 (NRC, 2016c).

3.3 Streams and Rivers

The licensee reported in its FHRR that the reevaluated flood hazard, including associated effects, for streams and rivers is based on stillwater-surface elevations in the Toussaint River of 576 ft (175.6 m) IGLD55. However, wind-wave effects associated with a PMF on the Toussaint River were not evaluated. The licensee alternatively reported those effects in the context of the tsunami flooding hazard (Section 3.6). This flood-causing mechanism is discussed in the licensee's CDB, which states that the CDB PMF elevation for streams and rivers is based on stillwater-surface elevations in the Toussaint River of 579 ft (176.5 m) IGLD55.

The licensee's reevaluation of flooding on streams and rivers described in the FHRR included three analysis components: (a) defining a PMP event, (b) simulating the PMF associated with the PMP event, and (c) evaluating the effect of combined flooding events. The licensee evaluated the PMF for the 139 mi^2 (360 km^2) Toussaint River drainage basin. The extent of the Toussaint River drainage basin and its three sub-basins is shown in Figure 3.3-1. The licensee stated in the FHRR (FENOC, 2015a) that the methods used in reevaluating flooding on streams and rivers were consistent with NUREG/CR-7046 (NRC, 2011).

For the purposes of the FHRR riverine analysis, the licensee modeled overland flow within the Toussaint River sub-basins following a simulated PMP event using the U.S. Army Corps of Engineers' (USACE) Hydrologic Engineering Center (HEC) Hydrologic Modeling System (HEC-HMS) computer code. Using the synthetic hydrographs produced from that computer model as input, the licensee continued to model river flow within the Toussaint River using the USACE's HEC-River Analysis System (RAS) computer code. The output from that computer analysis provided the PMF flow rate and maximum WSE reported in the FHRR.

3.3.1 Probable Maximum Precipitation

In developing a PMF estimate, NUREG/CR-7046 (NRC, 2011) recommends that three hydrologic scenarios be considered to ascertain which precipitation scenario would produce the maximum (highest) WSE at a reactor site:

- PMP Alternative 1 – a combination of mean monthly base flow; median soil moisture; antecedent rain; the all-season PMP; and the 2-yr wind waves along the critical direction.
- PMP Alternative 2 – a combination of mean monthly base flow; snowmelt from the probable maximum snowpack; a 100-yr, cool-season rainfall event; and 2-yr wind waves along the critical direction.
- PMP Alternative 3 – a combination of mean monthly base flow; snowmelt from a 100-yr snowpack; the cool-season PMP; and 2-yr wind waves along the critical direction.

All three precipitation scenarios were later evaluated by the licensee for the purposes of the Davis-Besse FHRR. The 2-yr wind-induced waves are analyzed in a subsequent calculation in the FHRR analysis (Section 3.7) and were therefore not assessed within the evaluation of the stream flooding mechanism by the licensee. The licensee assumed that Alternative 1 would not have initial infiltration due to full saturation caused by the antecedent storm, and Alternatives 2 and 3 would not have initial and constant infiltration as the ground is assumed to be frozen.

3.3.1.1 PMP Alternative 1

The licensee estimated the all-season PMP values using HMR 51 (Schreiner and Reidel, 1978) and HMR 52 (Hansen, Schreiner, and Miller, 1982). Twenty one randomly selected storm centers occurring throughout the Toussaint River watershed were evaluated by the licensee using the HMR 52 software (USACE, 1987), consistent with HMR 52 isohyets and recommendations. As the storm center with the greatest precipitation will not necessarily produce the largest peak discharge (and runoff), the licensee evaluated all 21 estimated PMP values as described in a calculation package referenced in the FHRR.

To ensure that all precipitation events capable of maximizing surface runoff were considered, five temporal storm distributions (so-called Alternative A in NUREG/CR-7046) were also considered. Those distributions place the peak precipitation at the front, one-third, center, two-thirds, and end of the storm event. The five temporal distributions for the PMP event described in Alternative A were also assessed by the licensee as part of PMP FHRR Alternatives 2 and 3 (described below). The antecedent storm specified for PMP Alternative 1 is defined in NUREG/CR-7046 as the lesser of either a 72-h storm that is 40 percent of the size of the all-season PMP, or a 500-yr storm followed by a 72-h dry period prior to the PMP event. The licensee chose as the antecedent storm the 40 percent PMP storm. The total precipitation for PMP Alternative 1 used in the licensee's HEC-HMS model corresponded to a 72-h storm at 40 percent of the all-season PMP, followed by a 72-h dry period, followed thereafter by the 72-h all-season PMP.

3.3.1.2 PMP Alternative 2

To calculate the 100-yr cool-season precipitation estimate, the licensee initially relied on the precipitation-frequency atlas (specifically "Atlas 14") published as Bonnin et al. (2006). Using that information source, location-specific all-season rainfall values were estimated for the Davis-Besse site and then adjusted spatially using area-depth reduction factors (Herschfield, 1961). To adjust those precipitation values to approximate a cool-season rainfall event, the guidelines described (Huff and Angel, 1992) were then used to calculate an all-season/cool-season ratio needed to estimate a 100-yr storm. Lastly, the intermediate hourly, cool-season rainfall depths for a 100-yr storm were estimated by the licensee iteratively, through trial-and-error, in order to fit a curve to approximate the data trend.

This alternative also calls for the consideration of the contribution of snowmelt from the probable maximum snowpack to the overall precipitation flux. Snowmelt conditions within the Toussaint River watershed were calculated by the licensee consistent with guidelines prepared by the USACE (1998). The snowmelt rate (energy budget) equations and constants recommended by ANSI/ANS-2.8-1992 (generally viewed to represent conservative parameter estimates) were then used by the licensee to estimate snowmelt rates for the Toussaint River watershed, where the probable maximum snowpack was assumed to be equal to unlimited snowpack during the entire coincident rainfall. This process was described in a calculation package referenced in the FHRR.

3.3.1.3 PMP Alternative 3

The licensee used an HMR 53 (Ho and Reidel, 1980) ratio of a 10-mi^2 (26-km^2), 6-h all-season PMP and a 10 mi^2 (26km^2) cool-season PMP for each month for which there was measurable snow. Similar to the method for estimating the probable maximum snowpack, the snowmelt value corresponding to the 100-year snowpack was calculated by the licensee consistent with a procedure recommended by the USACE (1998). The licensee estimated the 100-year snowpack depth near the reactor site using the National Oceanic and Atmospheric Administration (NOAA) Report "Precipitation Frequency Data Server" (NOAA, 2016c). A rain-on-snow condition was chosen for the snowmelt calculations, and was estimated based on dew point temperatures (not adjusted for measurement height), wind velocity (adjusted for measurement height), precipitation rate, and a basin wind coefficient. The inches per hour snowmelt rates were summed with the hourly, cool-season precipitation values by the licensee, in order to establish the snowmelt input for Alternative 3.

The NRC staff reviewed the licensee's estimation of PMP against relevant regulatory criteria based on present day methodologies and regulatory guidance. The methods presented in the HMRs referenced by the licensee are considered reasonable methods for estimating PMP values. The ANSI/ANS-2.8-1992 methods for snowmelt calculation are also considered appropriate. The staff reviewed the licensee's detailed process for determining all precipitation events (including snowmelt) for the three alternatives without finding errors.

3.3.2 Probable Maximum Flood

Three estimates of PMP occurring within the Toussaint River watershed were prepared by the licensee. Those estimates were subsequently converted to surface runoff (overland flow) using Version 3.5 of the USACE's HEC-HMS computer code (USACE, 2010b). Both the Toussaint

River and its attendant watershed are ungauged, so the licensee alternatively prepared a synthetic hydrograph in connection with the rainfall-to-runoff transformation using the Synder method (1938). To conservatively represent the extreme events being modeled, the estimated peak discharge was increased by one-fifth, as suggested in NUREG/CR-7046. The HEC-HMS calculation was limited to Basin 3 of the Toussaint River watershed (Figure 3.3-1) as that portion of the basin is contiguous with the Davis-Besse site.

Based on the characteristics of the alternatives suggested by NUREG/CR-7046, PMP Alternatives 2 and 3 are assumed to occur while the ground is frozen, preventing losses due to infiltration. Infiltration rates for PMP Alternative 1 were determined by the licensee from suggested ranges cited in U.S. Department of Agriculture's (USDA) "Urban Hydrology for Small Watersheds" (USDA, 1986), and classified by hydrologic soil groups. Because of the antecedent storm in Alternative 1 PMP, the infiltration rates used by the licensee were consistent with those of saturated soils.

The antecedent storm was also assumed to fully saturate the ground, preventing any initial infiltration losses. The percentage of land surface (including water surfaces) for each basin judged to be impervious was determined by using the U.S. Geological Survey's (USGS's) National Land Cover Database (USGS, 2016).

In addition to the precipitation inputs, the licensee also provided information on estimated base flow within the Toussaint River. In the absence of gauged data for the Toussaint River, the licensee alternatively relied on gauged data for the Portage River, another east-to-west flowing river system approximately 40 mi (64 km) long with a drainage area of approximately 612 mi^2 (1,585 km^2) located farther to the south. Both the Toussaint and the Portage Rivers are co-located within the same hydrologic unit code boundary and share both similar geography and meteorology. The licensee suggested that both rivers share similar hydrologic characteristics and thus the Portage River would be a reasonable hydraulic analog for the Toussaint River. Consistent with ANSI/ANS-2.8-1992, the base flow estimated for the Toussaint River was the mean monthly flow estimated for the Portage River.

Using the synthetic PMF flow hydrographs produced from the HEC-HMS computer code, the licensee then modeled river flow within the Toussaint River using Version 3.5 of the HEC-RAS computer code (USACE, 2010b). The output from that computer analysis provided the PMF flow rate and maximum WSE reported in the FHRR. The licensee noted that the geometry of the Toussaint River was developed using HEC-GeoRAS (Version 10.1), an ArcGIS tool set, and created cross sections spaced accordingly to achieve accurate results, hydraulic stability, and at locations of hydraulic structures such as bridges. Two bridge crossing locations were modeled with information provided by the Ohio Department of Transportation and ArcGIS imagery, while two additional bridges located further than 7 mi (11 km) from the reactor site were assumed not have a measurable effect on computational results due to their distance from the reactor site. River banks, blocked obstructions, and ineffective flow areas were delineated using contours created from the surface model and using geospatial imagery in ArcGIS as background maps. The outflow hydrograph for Basin 2 was developed in the HEC-HMS model and was used as the upstream boundary condition for the PMF model. As a downstream boundary condition for the HEC-RAS model, the licensee used the highest observed water level in Lake Erie, 574.5 ft (175.1 m) NAVD88. The licensee-assigned Manning's n coefficient values for the floodplain and channel that were judged to be conservative (at the high end of the expected ranges given the land cover types) based on "Open Channel Hydraulics" (Chow, 1959). Manning's n values were the same as those determined in the HEC-HMS modeling. This approach is consistent with the Hierarchical Hazard Assessment (HHA) approach described in NUREG/CR-7046 (NRC, 2011).

The licensee evaluated all three precipitation scenarios using the HEC-RAS computer code. Based on the HEC-RAS computer simulations, the licensee reported that the PMP Alternative 1 scenario produced the highest estimated WSE on the Toussaint River of 576 ft (175.5 m) IGLD55, which represents the maximum (controlling) flood hazard at the site and corresponds to a maximum flow rate of 100,436 cubic feet per second (cfs). The maximum estimated WSE is 8.0 ft (2.5 m) below the finished site grade elevation (584 ft (178.0 m) IGLD55) and 9.0 ft (2.8 m) below the elevation to which Davis-Besse safety-related structures are protected. Because Revision 30 to the licensee's updated UFSAR (FENOC, 2014) previously identified a maximum WSE of 579 ft (176.5 m) IGLD55 for the PMF, the maximum WSE for the reevaluated flood-causing mechanism is 3.0 ft (0.9 m) below the CLB, despite the highly-conservative nature of the models relied on as part of that reevaluation.

To complete its review of the licensee's PMF flood analysis, the staff requested that the licensee provide certain HEC-HMS computer files used to produce the results described in its FHRR. In response, the licensee provided the requested input/output (I/O) files associated with the PMF calculation. The files provided consisted of a series of computer simulation cases all relying on conservative modeling assumptions. The staff evaluated the licensee's basis for the infiltration loss model, the unit hydrograph approach, and the channel routing in the calculation of PMF discharge using the HEC-HMS model. Using the input files obtained from the licensee, the staff also evaluated the configuration of the HEC-HMS models used in the evaluation of flood depth and duration. The staff confirmed that the licensee's analysis was consistent with the information described in the FHRR. The use of the Portage River as a hydrologic analog for flow conditions within the Toussaint River is considered reasonable as the physical dimensions of that waterway are generally larger than those of the Toussaint River and thus would be expected to produce more-conservative modeling results if transposed onto the smaller river system. The staff also determined that the licensee's approach was consistent with and supported by the available information, and was consistent with the HHA approach described in NUREG/CR-7046 (NRC, 2011). In connection with the staff's review of this particular flood hazard, the staff identified two issues that were later addressed by the licensee in a July 2015 audit (NRC, 2016b). First, the staff noted the need for calibration of the licensee's HEC-RAS model. In response, the licensee noted that it employed the HHA modeling approach discussed in Section 2 of NUREG/CR-7046. The licensee noted that the HHA is a progressively refined, stepwise estimation of the site-specific hazards that evaluates the safety of pertinent SSCs with the most conservative plausible assumptions consistent with available data. For the purposes of the HEC-RAS model, the licensee reported during the July 2015 audit (NRC, 2016b) that it had used conservative plausible modeling assumptions and the results indicated the reactor site would not be inundated. The staff finds this conservative modeling approach to be reasonable and consistent with the HHA approach.

During the July 2015 audit (NRC, 2016b), the staff also questioned the reasonableness of using a uniform Manning's roughness coefficient value for the entire reach of the Toussaint River model. The licensee estimated that the ground cover along the entire length of the Toussaint River floodplain is comprised of cultivated agriculture in the range of 70 to 83 percent. Therefore, the licensee considered selecting a uniform Manning coefficient to represent the entire reach of the floodplain to be an appropriate modeling assumption. Furthermore, the licensee observed that the most conservative (highest) Manning's value from the applicable range of options for agricultural crop cover was selected for use in the HEC-RAS model. Lastly, the licensee argued that this modeling approach corresponds to the NUREG/CR-7046 HHA philosophy in which where the most conservative applicable assumptions should be used and if the site is not flooded, no refinement is needed. The staff concluded that the licensee's approach to these modeling issues was reasonable and meets the general intent of the 50.54(f) letter.

Upon review, the NRC staff determined that the reevaluated maximum PMF hazard elevation on the Toussaint River predicted by the licensee is well-below the Davis-Besse site and is also below the CDB flood elevation. The staff also reviewed the licensee's estimation of the PMF WSE against relevant regulatory criteria based on present day methodologies and regulatory guidance, and determined that the methods presented in the USACE's HEC suite of computer codes referenced by the licensee are considered reasonable methods for estimating PMF values. The NRC staff reviewed the licensee's detailed modeling process without finding errors.

3.3.3 Conclusion

In summary, the NRC staff confirmed the licensee's conclusion that the reevaluated PMF attributed to streams and rivers is bounded by the current design basis for this hazard at the Davis-Besse site. Therefore, the NRC staff determined that flooding from streams and rivers does not need to be analyzed in a focused evaluation or a revised integrated assessment.

3.4 Failure of Dams and Onsite Water Control/Storage Structures

The licensee reported in its FHRR that the reevaluated hazard, including associated effects, for dam-related flooding effects does not impact the Davis-Besse site. Furthermore, this flood-causing mechanism is not described in the licensee's CDB.

The Toussaint River/Creek system is a 37-mi (60-km) long, west-to-east flowing river immediately to the south of the Davis-Besse site; there are no dams *per se* or other regulated hydrologic structures physically located on the river system. However, the licensee reported that there are two storage features within the watershed that the reactor site shares with the Toussaint River system. One is a sewage storage lagoon associated with the operation of a municipal waste treatment plant in the Community of Genoa, Ohio. The other is also a storage lagoon associated with an open-pit mining operation (the Graymont Dolime quarry), also in Genoa. Both storage features are adjacent to each other and located approximately 15 mi (24 km) southwest of the Davis-Besse site, and are identified in the USACE's National Inventory of Dams (NID) data base (USACE, 2016). However, both storage structures are considered to be "off stream," in that they are not adjacent to the Toussaint Creek/River. The licensee reported that it had analyzed the effects of dam failures on WSEs at the reactor site using the simplified approach outlined in JLD-ISG-2013-01 (NRC, 2013b).

The methodology used by the licensee to evaluate the consequences of a dam breach was the peak outflow method without attenuation as discussed in "Earth, Dams and Reservoirs" (SCS, 1990). The methodology relies on using reservoir data, such as that reported in the NID, to estimate peak discharges from all upstream dams. Having calculated the cumulative estimated peak dam discharge, the licensee used that parameter value as additional inflow to the HEC-RAS PMF model for the reactor site. Conservatively, the licensee assumed that discharge from both dams arrives at the reactor site simultaneously so as to maximize the potential WSE estimate. Furthermore, the peak dam breach inflow value is applied at the same time the peak PMF occurs at the site. Through this approach, the licensee reported that the estimated peak WSE elevation attributed to dam failure occurring in combination with the PMF on the Toussaint River was 577.1 ft (175.9 m) NAVD88, of which 0.2 ft (0.05 m) of elevation was attributed to the hypothetical failure of the two dams located in Genoa. Overall, the licensee reported that the combined PMF/dam failure flooding scenario results in an estimated WSE that is approximately 8 ft (2.4 m) below the finished grade for the Davis-Besse site.

In connection with its independent review of the FHRR, the NRC staff confirmed that the two dams identified by the licensee co-occupy the Toussaint River watershed along with the Davis-Besse site. The staff also confirmed that the NID-reported dimensions of the two dams (water depth and impoundment volume) were the same as those used by the licensee in its FHRR analysis. Using those data, the staff estimated a WSE for dam failure at the reactor site using a bounding calculation approach based on empirical hydraulic equations; as a conservatism, there are no fluid mass losses assumed due to infiltration or attenuation. Using the U.S. Bureau of Reclamation's (USBR's) recommended dam breach flow equations to estimate peak outflow (USBR, 1982, 1983), the dam breach outflow (independently estimated from the two simultaneous dam failures) is instantaneously transferred to the reactor site location. The peak outflow quantity value was subsequently used in connection with Manning's velocity equation. Relying on a conservative estimate of the geometry of the Toussaint River at the Route 2 (CR2) Bridge/West Lakeshore Drive location (the location near the site where the river width is the narrowest due to the bridge overpass), the staff's estimated WSE due to dam failure was approximately equal to that estimated by the licensee in its FHRR, and well below the site grade of the reactor complex. Finally, after a review of maps and photographs of the Davis-Besse site, the staff determined that there were no on-site water control/storage structures that could produce floods within the footprint of the powerblock.

In summary, the staff confirmed the licensee's conclusion that the PMF from the failure of dams or onsite water control or storage structures does not impact the Davis-Besse site. Therefore, the NRC staff determined that flooding from failure of dams or onsite water control or storage structures does not need to be analyzed in a focused evaluation or a revised integrated assessment.

3.5 Storm Surge

The licensee reported in its FHRR that the reevaluated storm surge stillwater elevation is 585.8 ft (178.55 m) IGLD55, and the maximum total water surface elevation, including associated effects, is 585.9 ft (178.58 m) IGLD55. This flood-causing mechanism is described in the licensee's CDB. The CDB stillwater elevation for flooding due to storm surge at the site is 583.7 ft (177.9 m) IGLD55, while the maximum total water surface elevation, including associated effects, is 590.3 ft (179.9 m) IGLD55.

In Section 3.5.3 of its FHRR, the license provided general information on different types of storm types (synoptic, squall line, and hybrid) that could potentially impact the Great Lakes region in order to identify which event would generate the maximum storm surge and seiche at the site. The FHRR also described how the licensee quantified and plotted each storm's input parameters based on the location of low/high pressure centers and concurrent wind/pressure fields, and how the storms of interest evolved in both time and space.

For the purposes of the FHRR, the licensee stated that historical maximum storm surge is considered to be the largest of the yearly maximum storm surge heights. Storm surges were calculated using monthly data obtained from the Toledo (NOAA Station 9063085) and Marblehead (NOAA Station 9063079) stations. Those data stations represent the difference between measurements of monthly maximum and monthly mean WSEs based on USACE guidance (USACE, 2002). The licensee developed a Log Pearson III statistical analysis of those monthly data (i.e., the difference between the monthly maxima and mean) to determine a 25-year storm surge height based on the yearly maximum storm surge heights. The estimated 25-year surge height provided data necessary for calculating combined flooding scenarios. The licensee also conducted a site-specific climatological study for the Davis-Besse site, which identified 45 candidate probable maximum wind storm (PMWS) events, 16 squall lines, and 31 synoptic storms.

Through these efforts, the licensee's Log Pearson III 25-yr storm surge estimate at the Davis-Besse site is 4.4 ft (1.3 m). Using Toledo station data from an April 1966 storm, the licensee estimated a maximum historical storm surge of about 5.3 ft (1.6 m) at the site. When considering a storm from June 17, 1973, the license reported that the maximum recorded seiche amplitude at the site was 1.2 ft (0.4 m). The staff concluded that the licensee reviewed a reasonably large catalog of storm events sufficient to provide the basis for the definition of a PMWS for the reactor site. The staff further concluded that the licensee identified and described the relevant storms and surges. The staff also agrees with the licensee's findings that indicate that Lake Erie WSEs due to surge are generally higher than those attributed to seiche.

The licensee applied forcing from candidate PMWS events within a calibrated Delft3D computer code (Deltares, 2016) to evaluate WSEs near the reactor site. Based on the Delft3D modelling results, the PMWS candidate storm producing the highest WSE at the site was designated as the critical (controlling) probable maximum storm surge (PMSS). The licensee reported in its FHRR that for all candidate PMWS events, the Delft3D simulations suggest that remnants from Hurricane Sandy (October 2012 wind storm) represented the critical PMWS event. For this storm, maximum wind speeds were 103.1 mph (165.96 km per hour), minimum pressure of 29 in.-Hg (981.96 mbars), and a WSE of 586.7 ft (178.8 m) IGLD85 at the location.

The licensee stated in its FHRR, that the PMSS models developed for the Davis-Besse site were consistent with JLD-ISG-2012-06 (NRC, 2012) and ANSI/ANS 2.8-1992 (1992). Consequently, an antecedent water level equal to the 100-year maximum recorded water level at the site was considered in the WSE estimate. The licensee did not analyze for a maximum-controlled WSE because there are no water level control structures on Lake Erie to artificially control water elevations in the lake.

The FHRR stated that the 100-year high WSE in Lake Erie is 574.3 ft (175.0 m) IGLD85 based on a Log Person Type III distribution of 108 years of monthly mean water level data for the Toledo Weather Station and 55 years of data for the Marblehead Weather Station.

The FHRR (and the calculation packages referenced in that document) describe how the licensee applied the Delft3D-FLOW (hydrodynamic) and Delft3D-WAVE (spectral wave) computer codes to model storm surge and wave behavior at the reactor site. Coupling the Delft3D WAVE and FLOW computer codes allowed the numerical simulations to include the effects of wave setup. Based on its review of these calculations, the staff concludes that the licensee used appropriate procedures for the statistical analyses of Lake Erie's mean monthly water level. The staff agrees with the licensee's assessment that the number of historic data records is sufficient to conduct an accurate frequency analysis of the WSE at the site. For the storm surge simulations, the staff concludes that the licensee appropriately selected the antecedent water level set at the 100-year water level of 574.3 ft (175.0 m) IGLD85 for the requisite analyses.

The FHRR stated that the NOAA Geophysical Data Center website (NOAA, 2016b) provided the nearshore topographic and bathymetric data for Lake Erie for use in the Delft3D computer model; those data have a resolution of 3 arc seconds (295.3 ft (90.0 m)). The NOAA data are reported to have a horizontal accuracy of 1,640 ft (500 m) at nearshore locations and of 1,640 ft to 8,202 ft (500 m to 2,500 m) in open water (lake) areas; the vertical accuracy of those data is 3.3 ft (1.0 m). It was reported that the "Ohio Geographically Referenced Information Program's" digital elevation models (State of Ohio, 2016) were also used to obtain finer-resolution light detection and ranging elevation data; those data are reported to have a resolution of 2.5 ft (0.8 m). In the horizontal direction, the data are reported to be accurate to ±2.5 ft (0.8 m) with a vertical accuracy of ± 1.0 ft (0.3 m). The staff compared the Delft3D grids bathymetry to the flexible, unstructured Lake Erie model mesh applied in the Federal Emergency Management Agency (FEMA) Region 5 U.S. Army Engineer Research and Development Center (ERDC) "Great Lakes Storm Surge Study" (ERDC, 2016), and concluded that the data used by the licensee provide a reasonable physical rendition of important topographic and bathymetric features in and around the Davis-Besse site and were of sufficient resolution to accurately estimate WSEs. For the purposes of the FHRR analyses, the licensee simulated three historical storms to serve as calibration and verification references for the computer simulations; the storms in question occurred in December 1985, April 1998, and October 2010. The licensee compared Delft3D-calculated WSEs and waves with observed data in the vicinity of Lake Erie for the three storm events. During the model calibration phase (using the April 1998 event), the licensee varied four different model parameters in the computer code to produce WSE estimates with results in close agreement with observed water level and wave data. Through these comparisons, the licensee determined that the modeled hydrographs generally captured the observed surge heights and hydrograph shape.

The staff independently verified the licensee's modeling results for the three confirmatory storms. Additionally, the staff compared modeled results to observed data to assess the predictive accuracy of the model. The staff concludes that the licensee's Delft3D model adequately replicates WSEs and wave conditions observed during three cited historical storm events. Only the April 1998 event produced storm surge in the vicinity of the Davis-Besse site and, as a consequence, there were only limited observed data available to assess the predictive accuracy of the model in the area of interest. However, at the Cleveland NOAA weather station (the closest weather station to the reactor site), the staff noted that the licensee's computer model was able to estimate peak surge within inches of the observed peak water level data.

Conservatively combining the remnants of the 2012 Hurricane Sandy with PMWS maximum wind speeds of 103.1 mph (165.96 kmh), the licensee estimated a PMSS WSE of 585.8 ft (178.6 m) IGLD55. In the FHRR, Table 3 summarizes the existing and revaluated flood WSEs at the Davis-Besse site, and notes that the CDB stillwater elevation of 583.7 ft (177.9 m) IGLD55 is not bounded by the reevaluated stillwater elevation of 585.8 ft (178.6 m) IGLD55 at the powerblock.

The staff evaluated and used the licensee's I/O files and independently reproduced the WSE values reported in its FHRR. Furthermore, to independently estimate a PMSS elevation for the Davis-Besse site, the staff developed and applied its own analyses for PMWS and PMSS. The staff's independent PMWS analysis for the region including the reactor site was based on NOAA's Climate Forecast System Reanalysis (CFSR) data (NOAA, 2016a), as well as ANSI/ANS 2.8-1992 (1992) guidance. The staff's independent PMSS calculation also relied on the licensee-developed and validated Delft3D FLOW/WAVE computer model. By including forcing, the staff derived a maximum WSE for the western Lake Erie region. The staff's storm surge analysis using the Delft3D computer model in concert with the PMWS events produced maximum WSE levels nearly equal to the storm surge WSE value estimated by the licensee. Accordingly, the staff concluded that the FHRR PMSS still water value proposed by the licensee was reasonable for the Davis-Besse site.

3.5.1 Total Water Level (Combined Effects Flood)

Table 3 of the FHRR lists the reevaluated WSE estimates of PMSS, which include the effects of wind-generated waves, specifically wave height, wind set-up, and wave run-up. The FHRR also states that Davis-Besse is surrounded by wave protection dikes located along portions of the northern, eastern, and southern flanks of the site with a top elevation of 591 ft (180.1 m) IGLD55. The licensee's wave action analysis concluded that there would be 4.0 ft (1.2 m) of wave run-up at the time of the maximum stillwater elevation (585.9 ft (178.6 m) IGLD55). This results in a total WSE of 589.9 ft (179.8 m) IGLD55 at the toe of the north-facing protective dike.

In its confirmatory analysis of PMWS and PMSS, the staff relied on NOAA's CFSR data, ANSI/ANS 2.8-1992 guidance, and the licensee's coupled Delft3D FLOW/WAVE computer model. The staff specified similar boundary conditions to the licensee in its independent computer simulations and at the same locations described in the licensee's calculation packages. The staff also used currently-recognized hydrologic equations described in the "Coastal Engineering Manual" (USACE, 2002), for evaluating wave run-up on a 2 percent sloped surface. The staff's estimated wave run-up values on the site's wave protection dike indicate total water levels similar to, or slightly below, those listed by the licensee in Table 3.0-1 of the FHRR. Specifically, the staff's confirmatory WSE simulations at locations near the powerblock indicated total water levels in the range of 585.4 ft (178.4 m), and 585.6 ft (178.5 m) IGLD55. These locations include those identified by the licensee in connection with LIP-related flooding.

3.5.2 Conclusion

In summary, the NRC staff confirmed the licensee's conclusion that the reevaluated stillwater elevation for flooding due to storm surge is not bounded by the CDB stillwater flood hazard at the Davis-Besse site. Therefore, the staff expects that the licensee will submit a focused evaluation or a revised integrated assessment for storm surge and associated site drainage.

3.6 Seiche

The licensee reported in its FHRR that the reevaluated hazard, including associated effects, for seiche-related flooding does not impact the Davis-Besse site. Further, this flood-causing mechanism is not described in the licensee's current design basis.

The licensee stated that the level of rise in Lake Erie due to seiche effects is significantly 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 that resonance is not a flood-causing mechanism of concern at the reactor site during the occurrence of PMWS.

The staff independently performed seiche calculations in Advanced Circulation Model based on Merian's Formula, which can be used to estimate the period of a harmonic wave. This independent analysis confirmed the licensee's conclusion that resonance is not a flood-causing mechanism of concern at the Davis-Besse site during the occurrence of a PMWS.

In summary, the NRC staff confirmed the licensee's conclusion that the reevaluated hazard for seiche-related flooding does not impact the Davis-Besse site. Therefore, the NRC staff determined that flooding from seiche does not need to be analyzed in a focused evaluation or a revised integrated assessment.

3.7 Tsunami

The licensee reported in its FHRR that the reevaluated hazard, including associated effects, for tsunami-related flooding does not impact the Davis-Besse site. This flood-causing mechanism is not discussed in the licensee's CDB.

The licensee did not consider a tsunami-like flooding scenario to be physically plausible at the reactor site as it is not in a geographic location generally recognized for the generation of tsunamis. The licensee's FHRR discusses three possible mechanisms for tsunami formation, submarine earthquakes, subaerial landslides, and volcanoes, but concludes that none of these scenarios are plausible at the Davis-Besse site. Specifically, the FHRR cited the absence of historically-reported or instrumentally-recorded earthquakes exceeding magnitude 7 that could generate a tsunami wave in Lake Erie. The FHRR also notes that the topography in the vicinity of the site is relatively flat and of low relief along the Lake Erie waterfront; therefore, the mass wasting events sufficient to displace the volume of water needed to generate a tsunami are unlikely to occur at this location. Finally, the FHRR states that there are no active volcanoes in the Lake Erie region which could generate a tsunami.

The NRC staff reviewed the flooding hazard from tsunami-related flooding, including associated effects, against the relevant regulatory criteria based on present-day methodologies and regulatory guidance. The staff noted four records of tsunami observations on Lake Erie in the National Geophysical Data Center (NGDC) historical tsunami database (NGDC, 2014) and bathymetry data, but these records arise from eyewitness accounts rather than from documented instrumentation and are considered questionable. Furthermore, Lake Erie is located within the geologically and seismically stable North American continental craton, which is not structurally connected to any inter-plate subduction zones (USGS, 2013), or active volcanic features (Smithsonian Institution, 2016) generally recognized for tsunami generation.

Therefore, the NRC staff concluded that only submarine landslides have the potential to generate tsunamis in Lake Erie, as there is evidence or records suggesting impulsive tsunamis have been generated in the past. Although several researchers observed erosion of bluffs along the shores of Lake Erie (Quigley et al., 1977, and Amin and Davidson-Arnott, 1995), the formation of tsunami-like waves when bluff material is eroded has not been mentioned. The staff conducted an independent modeling study to examine how a hypothetical tsunami generated in response to a submarine landslide occurring within Lake Erie might affect flood elevation levels at the Davis-Besse site. Based on the relatively low topographic relief along the western shores of Lake Erie, the staff identified the location of the controlling landslide source and used the COULWAVE (Cornell University Long and Intermediate Wave Modeling Package) computer program (Lynett and Liu, 2002) for the water-level analysis portion of the confirmatory tsunami simulation. The simulation produced a probable maximum tsunami WSE of 573.7 ft (174.9 m) IGLD55 in Lake Erie, 10.3 ft (3.1 m) below the site grade for the reactor complex of 584 ft (178.0 m) IGLD55. As a result, the staff concluded that tsunami-induced flooding does not impact the CDB at the Davis-Besse site.

In summary, the NRC staff confirmed the licensee's conclusion that the reevaluated tsunami-induced flooding does not impact the Davis-Besse site. Therefore, the NRC staff determined that flooding from tsunami does not need to be analyzed in a focused evaluation or a revised integrated assessment.

3.8 Ice-Induced Flooding

The licensee reported in its FHRR that the reevaluated flood hazard for ice-induced flooding is 574.0 ft (175 m) IGLD55 and does not impact the Davis-Besse site. This flood-causing mechanism is discussed in the licensee's CDB, but a maximum flood elevation was not reported.

For the purposes of the FHRR, the licensee consulted the USACE's Cold Regions Research and Engineering Laboratory (CRREL) ice jam database (USACE, 2015a) for reports of historic ice jams on the Toussaint River but found no recorded ice jams. However, because this waterway is ungauged and thus not subject to regular monitoring, the licensee expanded the search for reports of historic ice jams to nearby analog river systems that are also coincident with the Toussaint River, including the Portage River, Rock Creek, Bayou Ditch, and Lacarpe Creek. The licensee noted multiple reports of historic ice jams on these analog systems with the maximum reported flood level of 13 ft (4.0 m) along the Portage River.

Because of the possibility of ice jams occurring within the greater Toussaint River watershed, the licensee evaluated the consequences of a hypothetical ice jam on the Toussaint River at the previously described CR2 Bridge location (see Section 3.4), slightly to the southwest of the Davis-Besse site. In connection with that HEC-RAS analysis, the licensee assumed that the height of the ice jam was 8 ft (2.4 m), which corresponds to the nominal clearance of the CR2 Bridge above the Toussaint River. To accurately represent flow conditions within the Toussaint River at the time the ice jam event would most likely occur, the licensee relied on the cool-season Alternative 2 PMP as input to evaluate the effect of a postulated ice dam failure using the HEC-RAS model. The licensee reported that the resulting maximum WSE at the reactor site from an upstream ice jam was 574.0 ft (175 m) IGLDD55, approximately 11 ft (3.3 m) below the finished grade for the powerblock.

The staff reviewed the flood hazard potential from ice-induced flooding against the relevant regulatory criteria based on present-day methodologies and regulatory guidance. The staff also considered the CRREL database and confirmed that there were no reports of ice jam formation or ice dams occurring on the Toussaint River. However, freezing on Lake Erie is common as are past reports of freezing on the Portage River to the south of the Davis-Besse site. However, because the licensee's analysis confirmed that this flood-causing mechanism is bounded by other flood-causing mechanisms at the site, the staff did not perform an independent confirmatory calculation of this ice-induced flooding. The staff identified an inconsistency in the maximum WSE following an ice dam breach between the FHRR and a supporting calculation package. The inconsistency was later clarified during the July 2015 audit (NRC, 2016b), in which the licensee clarified that the maximum WSE following an ice dam breach is 575.1 ft (175.3 m) NAVD88.

In summary, the NRC staff confirmed the licensee's conclusion that ice-induced flooding alone could not inundate the site. The staff also confirmed the licensee's conclusion that the reevaluated hazard for ice-induced flooding does not impact the Davis-Besse site. Therefore, the NRC staff determined that ice-induced flooding does not need to be analyzed in a focused evaluation or a revised integrated assessment.

3.9 Channel Migrations or Diversions

The licensee reported in its FHRR that the reevaluated hazard, including associated effects, for channel migrations or diversions does not impact the plant site because this mechanism is not a potential contributor to flooding at the Davis-Besse site (FENOC, 2015a). This flood-causing mechanism is discussed in the licensee's CDB, but a maximum flood elevation was not reported because channel migration or diversion-induced flooding was determined not to be a potential contributor to flooding at the reactor site.

In its FHRR, the licensee discussed its review of topographic maps from multiple years showing the region in the vicinity of the reactor site, including the Toussaint River, the lakeshore, and lakeside wetlands. Comparisons show that in 1900, the locations of the both the lakeshore and the riverbanks differed by up to 0.1 mi (0.2 km) from their locations shown in the maps of 1952 to present, but that differences in lakeshore and riverbank locations from 1952 to present were minimal. Based on over 100 years of information, the licensee concluded that channel migration or diversion toward the site from the river or the lake is not probable.

The staff reviewed the flooding hazard potential from channel migrations or diversions, including associated effects, against the relevant regulatory criteria based on present-day methodologies and regulatory guidance, as described below. The staff reviewed the USGS's historic topographic map digital data base (USGS, 2015) to identify the earliest maps published for the area and then analyzed those maps for geomorphic evidence of channel diversion, including river meandering. The staff compared the results of this review to the more recently prepared map of the reactor site to see if there had been changes in the topography in the intervening years. The staff independently reviewed geo-referenced USGS topographic maps and aerial photography (i.e., NETROnline, 2016) for certain years (ranging from 1943 to 2006), in addition to aerial views available through *Google Earth*. The staff's review corroborated the information presented by the licensee.

In summary, the NRC staff confirmed the licensee's conclusion that flooding related to channel migrations or diversions does not impact the site. Therefore, the NRC staff determined that this mechanism does not need to be analyzed in a focused evaluation or a revised integrated assessment.

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

4.1 Reevaluated Flood Height for Hazards Not Bounded by the CDB

Section 3 of this staff assessment documents the NRC staff review of the licensee's flood hazard water height results. Table 4.1-1 contains the maximum flood height results, including wave effects, for flood mechanisms not bounded by the CDB. The staff agrees with the licensee's conclusion that LIP and storm surge are the hazard mechanisms 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. For the storm surge flood hazard, the NRC staff anticipates the licensee will perform an additional assessment of plant response, either a focused evaluation or an integrated assessment, as discussed in COMSECY-15-0019 (NRC, 2015c) and JLD-ISG-2016-01, Revision 0 (NRC, 2016c).

4.2 Flood Event Duration for Hazards Not Bounded by the CDB

The staff reviewed information provided in FENOC's 50.54(f) response (FENOC, 2015; NRC, 2016b) regarding the FED parameters needed to perform the additional assessments 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; the staff views the values reported reasonable based on the magnitudes of the estimated flooding hazards.

However, the licensee did not provide the FED values for both the time for the LIP event to reach the maximum reported WSE at the impacted door locations (Table 4.2-2) as well as the recession time for water egress generally from the site.[1] The warning time for the storm surge event was also not reported.[2] The licensee is expected to develop FED parameters for these flood-causing mechanisms in order to conduct the MSA and focused evaluations or integrated assessment as discussed in Appendix G of NEI-12-06, Revision 2 (NEI, 2015), and outlined in COMSECY-15-0019 (NRC, 2015c), JLD-ISG-2012-05 (NRC, 2012d), JLD-ISG-2012-01, Revision 1 (NRC, 2016a), and JLD-ISG-2016-01, Revision 0 (NRC, 2016c), respectively. The

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[1] For PMP Alternative 2, the maximum WSE estimated by the licensee was 574.2 ft (175.0 m) IGLD55 (corresponding to a maximum flow rate of 31,747 cfs (898.97 cubic meters per second [cms]). For PMP Alternative 2, the maximum WSE estimated by the licensee on the Toussaint River was 575.1 ft (174.9 m) IGLD55 (corresponding to a maximum flow rate of 61,943 cfs [1,754 cms]).

[2] In its revised FHRR, the licensee reported that the general area to the west and south of the site will experience flooding as a result of rising flood waters within the Toussaint River as it is hydraulically-connected to Lake Erie. In Revision 20 of the UFSAR (FENOC, 1996), the licensee previously noted that the average elevation of the marsh areas remained at 570 ft (173.7 m) IGLD55 as those areas had not undergone grade improvements during construction of the reactor. As a consequence, the non-diked locations of the reactor site are expected to allow flood waters to freely intrude into the powerblock yard consistent with a rise in the WSE of the Toussaint River estuary during a PMSS to the level estimated by the licensee.

NRC staff will review these FED parameters as part of future additional assessments of plant response, if applicable to the assessment and hazard mechanism.

4.3 Associated Effects for Hazards Not Bounded by the CDB

The staff reviewed information provided in FENOC's 50.54(f) response (FENOC, 2015, NRC 2016b) regarding AE parameters needed to perform future additional assessments of plant response for flood hazards not bounded by the CDB. The AE parameters directly related with maximum water elevation, such as wave effects, are provided in Table 4.1-1. The AE parameters not directly associated with total water elevation are listed in Table 4.3-1. The AE parameters not submitted as part of the FHRR are noted as "not provided" in Table 4.3-1. The staff will review these AE parameters as part of future additional assessments of plant response, if applicable to the assessment and hazard mechanism.

The licensee reported hydrostatic and hydrodynamic loads at impacted door locations due to LIP-related flooding at the Davis-Besse site. Based on the relatively low flood depths and corresponding flow velocities, the staff agreed that these associated effects are minimal and the results reported in Table 4.3-1 are reasonable. The licensee is expected to develop the missing AE parameters for the storm surge flood-causing mechanisms to conduct the additional assessment. For the AE parameters provided, the staff confirms the licensee's AE parameter results are reasonable for use in additional assessments.

4.4 Conclusion

Based upon the preceding analysis, the staff confirms 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 and COMSECY-15-0019, "Mitigation Strategies and Flooding Hazard Reevaluation Action Plan" (NRC, 2015a).

The licensee is expected to develop FED parameters and applicable flood associated effects to conduct future additional assessments as discussed in Appendix G of NEI 12-06, Revision 2 (NEI, 2015b); JLD-ISG-2012-05 (NRC, 2012d; and JLD-ISG-2016-01, Revision 0 (NRC, 2016c). The staff will evaluate the missing FED parameters (i.e., warning time, period of inundation, and recession time) marked as "not provided" in these tables as part of future assessments of plant response, if applicable to the assessment and hazard mechanism.

5.0 CONCLUSION

The NRC staff has reviewed the information provided for the reevaluated flood-causing mechanisms at the Davis-Besse site. Based on its review of the above available information provided in FENOC's 50.54(f) response (FENOC, 2014a, 2014b, and 2015, and NRC, 2016b), the staff concludes that the licensee conducted the hazard reevaluation using present-day methodologies and regulatory guidance used by the NRC staff in connection with ESP and COL reviews.

Based upon the preceding analysis, the NRC staff confirmed that the licensee responded appropriately to Enclosure 2, Required Response 2, of the 50.54(f) letter, dated March 12, 2012. In reaching this determination, the NRC staff confirmed the licensee's conclusions that (a) the reevaluated flood hazard results for LIP and storm surge are not bounded by the CDB flood hazard, (b) additional assessments of plant response will be performed by the licensee for LIP and storm surge mechanisms, and (c) the reevaluated flood-causing mechanism information is appropriate input to the additional assessments of plant response.

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

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

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

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

JLD-ISFG-2013-01 refers to the "Guidance for Assessment of Flooding Hazards Due to Dam Failure" (NRC, 2013b).

Table 3.1-1. Summary of Controlling Flood-Causing Mechanisms at the Davis-Besse Site Taken from FENOC (2015c).

REEVALUATED FLOOD-CAUSING MECHANISMS AND ASSOCIATED EFFECTS THAT MAY EXCEED DAVIS-BESSE POWERBLOCK ELEVATIONS*		ELEVATION** [IGLD55]
Local Intense Precipitation and Associated Drainage	Turbine Building	585.5 ft (178.46 m)
	Intake Structure	585.5 ft (178.46 m)
	Auxiliary Building	585.4 ft (178.43 m)
Storm Surge (within the Powerblock yard)		585.9 ft (178.58 m)
*Flood height and associated effects as defined in JLD-ISG-2012-05. **Elevation reported includes wind wave/run-up effects, if applicable to hazard.		

Table 3.2-1. FHRR-Reported Maximum Water Surface Elevations Due to LIP at the Davis-Besse (NRC, 2015b).

TURBINE BUILDING	ELEVATION [IGLD55]	AUXILIARY BUILDING	ELEVATION [IGLD55]
Door 330	585.4 ft (178.4 m)	Door 300	585.4 ft (178.4 m)
Door 333	585.4 ft (178.4 m)	Door 315	585.3 ft (178.4 m)
Door 334	585.5 ft (178.5 m)	Door 320A	585.3 ft (178.4 m)
Door 399	585.4 ft (178.4 m)	Door 324	585.3 ft (178.4 m)
Door 399A	585.4 ft (178.4 m)	Door 361	585.4 ft (178.4 m)
		Door 362	585.4 ft (178.4 m)
*Flood duration above 585 ft (178.3 m) IGDL55			

Table 3.1-1. Current Design Basis (CDB) Flood Hazard Elevations at the Davis-Besse Site

MECHANISM	STILLWATER ELEVATION [IGLD55]	WAVES/RUN-UP	DESIGN BASIS HAZARD ELEVATION [IGLD55]	FHRR REFERENCE (FENOC, 2015c)
Local Intense Precipitation and Associated Drainage *Turbine Building Location*	584.5 ft (178.16 m)	Minimal	584.5 ft (178.16 m)	Section 2.1.1
Streams and Rivers	579.0 ft (176.5 m)	N/A	579.0 ft (176.5 m)	Section 2.1.2
Failure of Dams and Onsite Water Control/ Storage Structures	No impact identified	No impact identified	No impact identified	Section 2.1.2
Storm Surge *Intake Structure*	583.7 ft (177.91 m)	6.6 ft (2.01 m)	590.3 ft (179.92 m)	Sections 2.1.4 and 2.1.8
Seiche	Not Included in CDB	Not Included in CDB	Not Included in CDB	Table 3
Tsunami	Not Included in CDB	Not Included in CDB	Not Included in CDB	Table 3
Ice-Induced	No impact identified	No impact identified	No impact identified	Table 3
Channel Migrations or Diversions	No impact identified	No impact identified	No impact identified	Table 3

Note 1: Reported values are reported as NAVD88 and rounded to the nearest one-tenth of a foot.

Note 2: Based on the NRC staff's independent (deterministic) hazard assessment using present-day regulatory guidance and methodologies of storm surge, the staff concludes that the site's current design basis remains bounded. For this reason, the staff concludes it is appropriate to utilize the current design basis storm surge elevation in conjunction with the mitigating strategies assessment.

Table 4.1-1. Reevaluated Flood Hazards for Flood-Causing Mechanisms Not Bounded by the CDB

FLOODING MECHANISM	STILLWATER ELEVATION [IGLD55]	ASSOCIATED EFFECTS [IGLD55]	REEVALUATED FLOOD HAZARD [IGLD55]	FHRR REFERENCE (FENOC, 2015c)
Local Intense Precipitation				
Turbine Building	585.5 ft (178.5 m)	Minimal	585.5 ft (178.5 m)	Section 3.8 Table 1
Intake Structure	585.5 ft (178.5 m)	Minimal	585.5 ft (178.5m)	
Auxiliary Building	585.4 ft (178.4 m)	Minimal	585.4 ft (178.4 m)	
Storm Surge				
Powerblock Yard	585.8 ft (178.6 m)	0.1 ft (0.03 m)	585.9 ft (178.6 m)	Section 3.7.4
Note: Reported values are rounded to the nearest one-tenth of a foot.				

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	< 1.25 hrs	Not Provided
Storm Surge *Powerblock Yard*	Not Provided	2.5 hrs	< 2.5 hrs
Note: The licensee has the option to use NEI guideline 15-05 (NEI, 2015a) to estimate the warning time necessary for flood preparation.			

Table 4.2-2. Period of Inundation above 585 ft (178.3 m) IGDL55 Due to LIP (NRC, 2015b).

TURBINE BUILDING	PERIOD OF INUNDATION (min)	AUXILIARY BUILDING	PERIOD OF INUNDATION (min)
Door 330	33 min	Door 300	24 min
Door 333	33 min	Door 315	33 min
Door 334	75 min	Door 320A	33 min
Door 399	33 min	Door 324	33 min
Door 399A	33 min	Door 361	33 min
		Door 362	33 min

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

LOCATION	MAXIMUM VELOCITY	MAXIMUM FLOW DEPTH	MAXIMUM HYDROSTATIC LOAD	MAXIMUM HYDRODYNAMIC LOAD	DEBRIS LOADING EFFECTS	SEDIMENT LOADING EFFECTS
Local Intense Precipitation and Associated Drainage						
Containment Structure	0.9 fps (0.28 mps)	1.92 ft (0.6 m)	120 lb/ft^2 (586 kg/m^2)	2 lb/ft^2 (9.8 kg/m^2)	Not Provided	Not Provided
Auxiliary Building	1.1 fps (0.3 mps)	1.90 ft (0.6 m)	119 lb/ft^2 (581 kg/m^2)	2 lb/ft^2 (9.8 kg/m^2)	Not Provided	Not Provided
Turbine Building	2.1 fps (0.6 mps)	1.65 ft (0.5 m)	103 lb/ft^2 (503 kg/m^2)	8 lb/ft^2 (39 kg/m^2)	Not Provided	Not Provided
Intake Structure	3.9 fps (1.2 mps)	0.8 ft (0.3 m)	53 lb/ft^2 (259 kg/m^2)	29 lb/ft^2 (142 kg/m^2)	Not Provided	Not Provided
Storm Surge						
Powerblock Yard	Not Provided	0.1 ft (0.30 m)	Not Provided	Not Provided	Not Provided	Not Provided
Intake Structure	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided

fps: feet per second
mps: meters per second

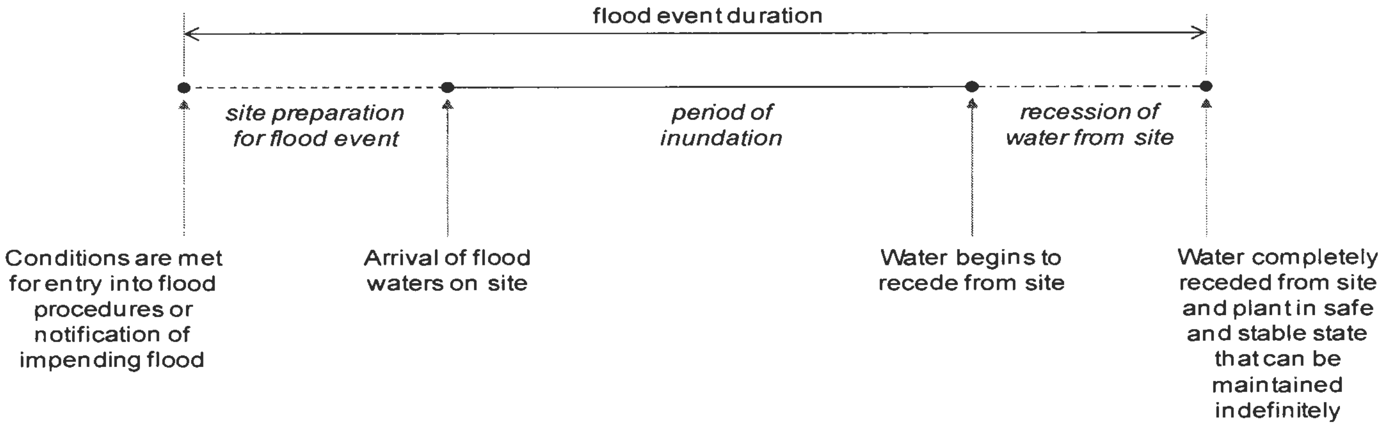


Figure 2.2-1 Flood Event Duration

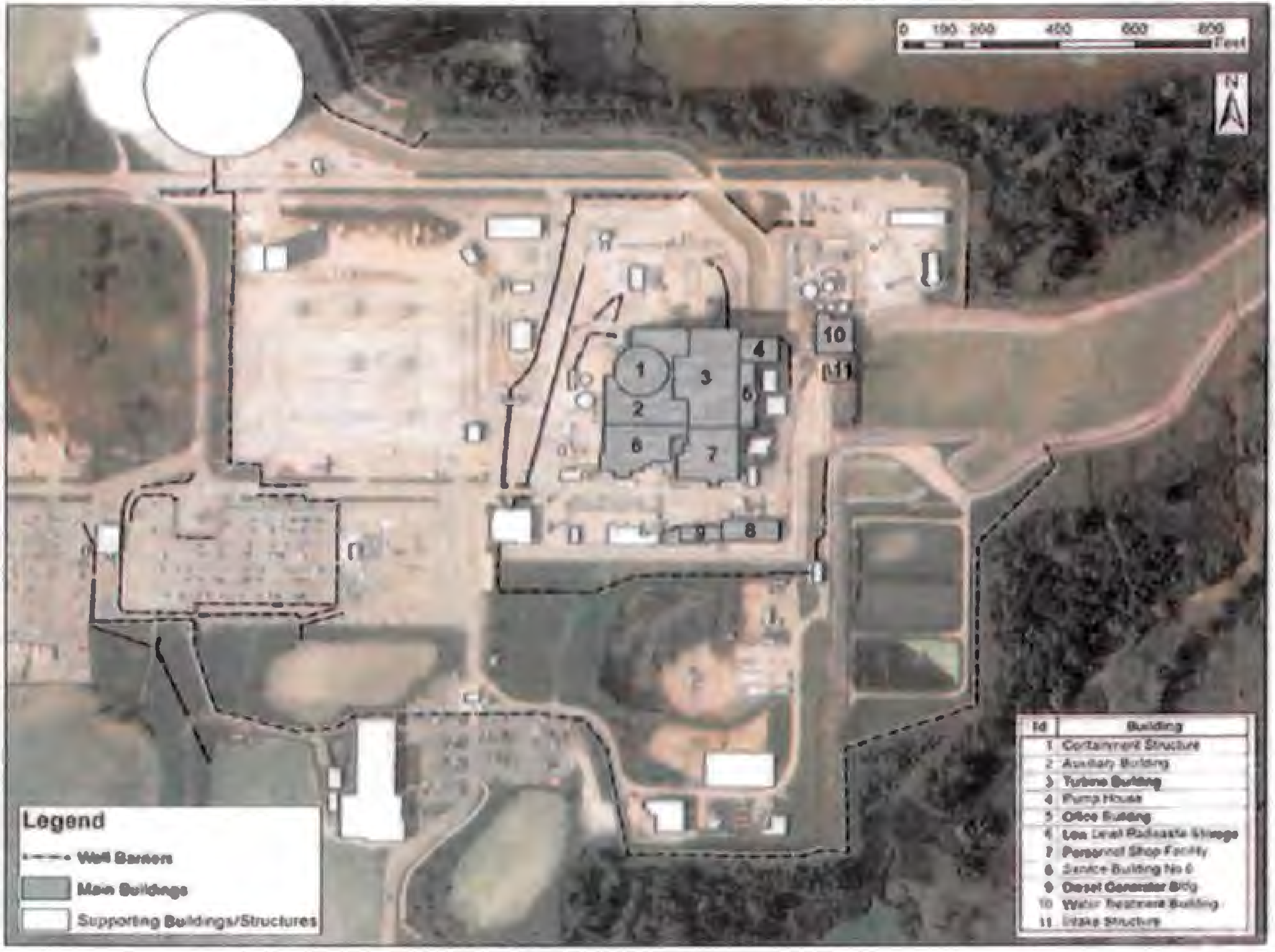


Figure 3.1-1. Key features of the Davis-Besse site that were depicted in the FLO-2D PRO computer model used to evaluate LIP. From FENOC (2015a).

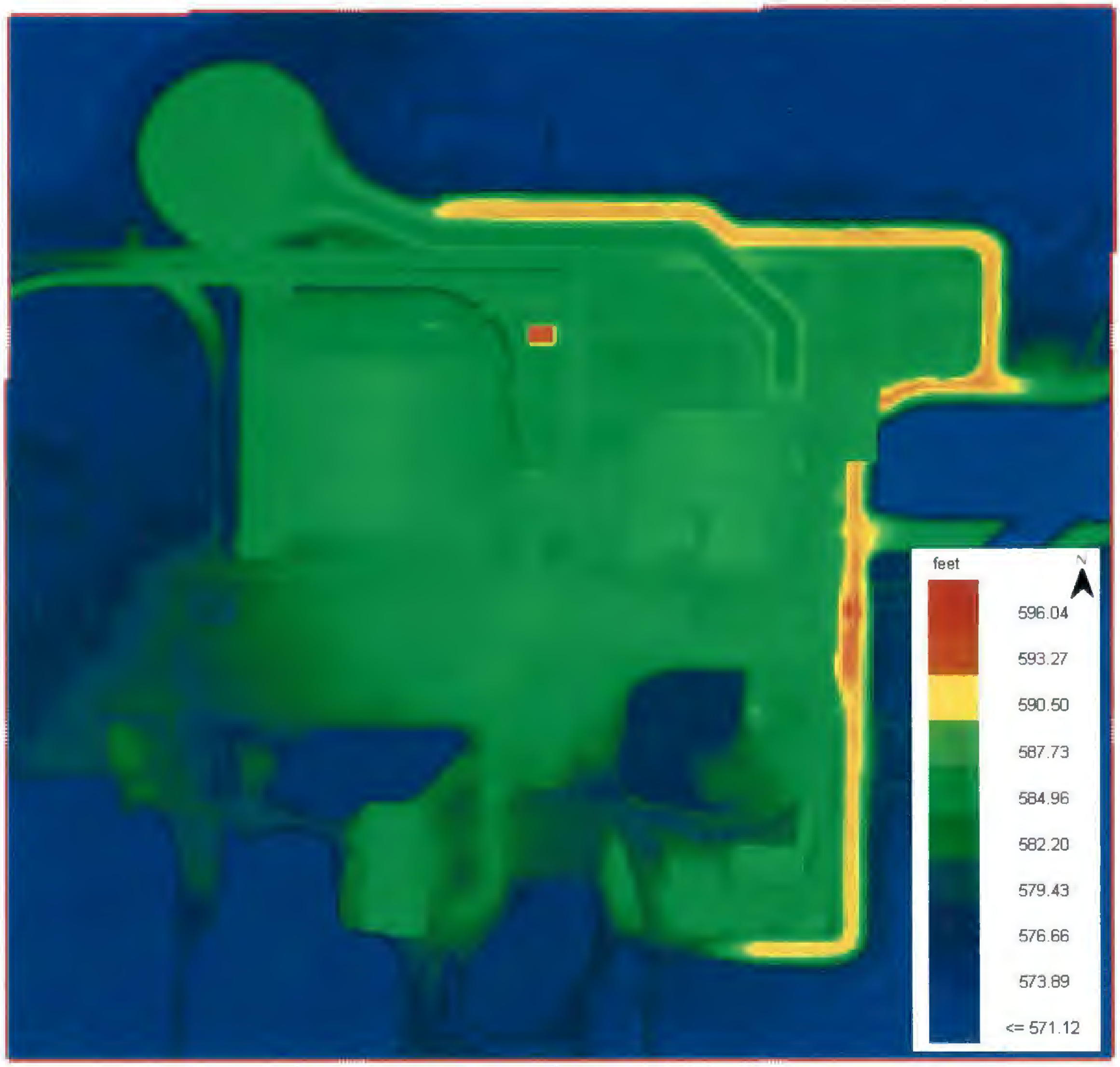
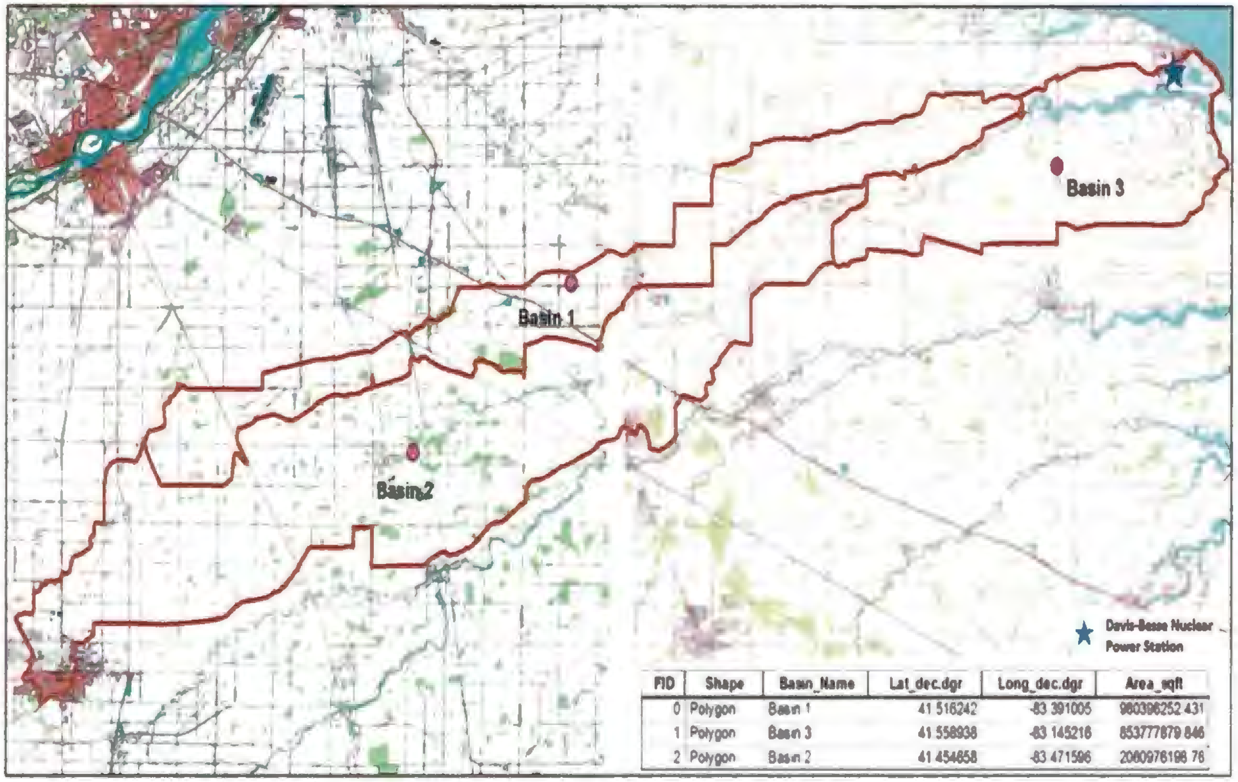
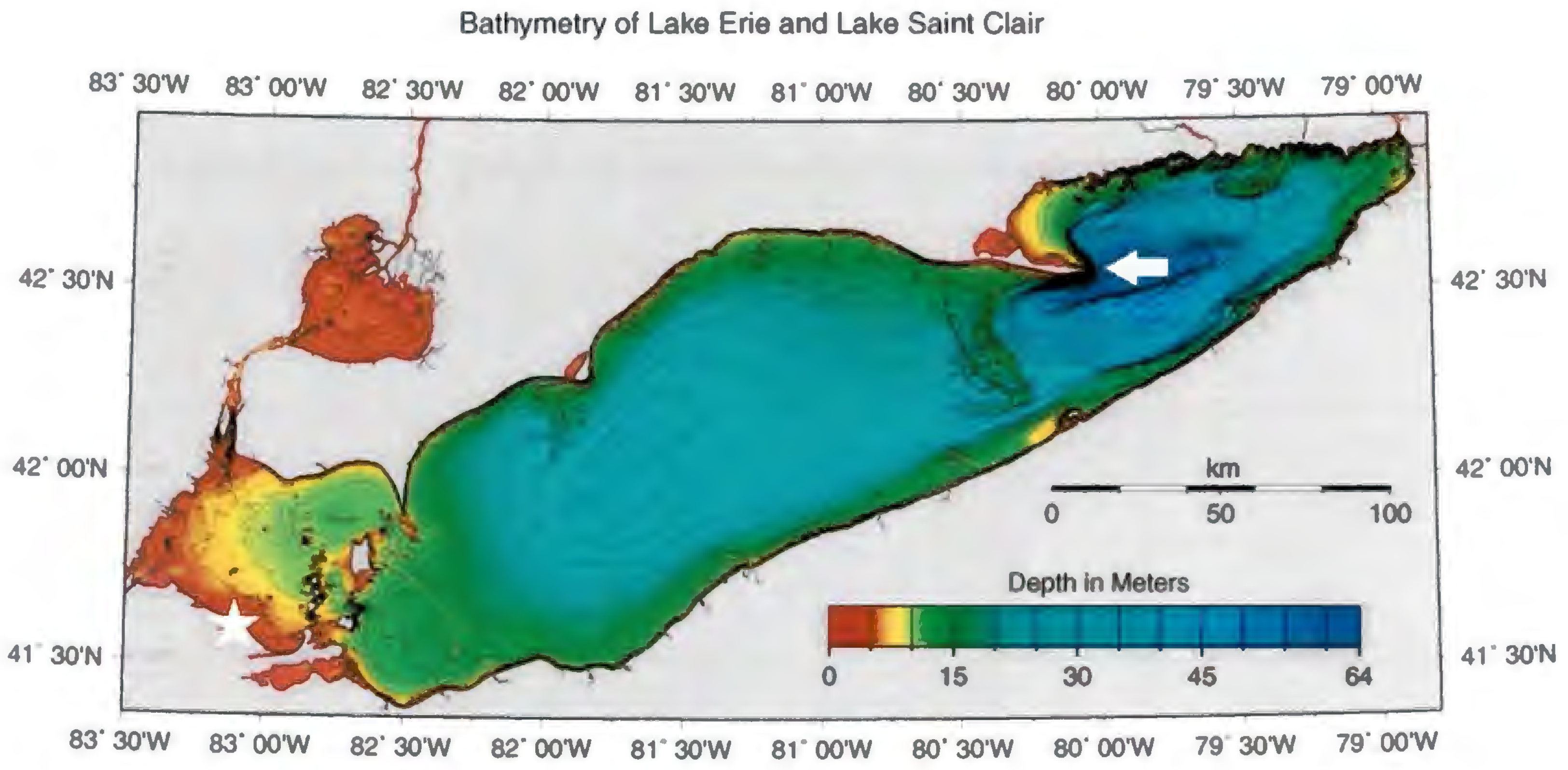


Figure 3.2-1. Davis-Besse topographic elevations depicted in the LIP computer model prepared using FLO-2D Pro (as revised). Elevations reported are NAVD88.



FID	Shape	Basin_Name	Lat_dec.dgr	Long_dec.dgr	Area_sqft
0	Polygon	Basin 1	41.516242	-83.391005	980396252.431
1	Polygon	Basin 3	41.558938	-83.145216	853777879.846
2	Polygon	Basin 2	41.454858	-83.471596	2060976198.76

Figure 3.3-1. Basins defining the Toussaint River watershed. Star designates the Davis-Besse site. Taken from FENOC (2015b).



Bathymetry of Lake Erie and Lake Saint Clair

Figure 3.7-1. Map Showing Long Point Escarpment in Relations to the Davis-Besse Site. The horizontal arrow on the right side of the figure identifies the location of the Long Point Escarpment. The star on the left side of the figure identifies the approximate location of the Davis-Besse site. Taken from http://ngdc.noaa.gov/mgg/greatlakes/ lakeerie_cdrom/html/e_gmorph.htm.

If you have any questions, please contact me at (301) 415-3809 or e-mail at Juan.Uribe@nrc.gov.

Sincerely,

/RA/

Juan Uribe, Project Manager
Hazards Management Branch
Japan Lessons-Learned Division
Office of Nuclear reactor Regulation

Docket No. 50-346

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Reevaluation Report

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