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

November 2, 2017

Mr. Bryan C. Hanson
Senior Vice President
Exelon Generation Company LLC
President and Chief Nuclear Officer
Exelon Nuclear
4300 Winfield Road
Warrenville, IL 60555

SUBJECT: THREE MILE ISLAND NUCLEAR STATION, UNIT 1 – STAFF ASSESSMENT OF RESPONSE TO 10 CFR 50.54(f) INFORMATION REQUEST – FLOOD-CAUSING MECHANISM RE-EVALUATION (CAC NO. MF1113)

Dear Mr. Hanson:

By letter dated March 12, 2012, the U.S. Nuclear Regulatory Commission (NRC) issued a request for information pursuant to Title 10 of the *Code of Federal Regulations*, Section 50.54(f) (hereafter referred to as the 50.54(f) letter). The request was issued as part of implementing lessons learned from the accident at the Fukushima Dai-ichi nuclear power plant. Enclosure 2 to the 50.54(f) letter requested licensees to reevaluate flood-causing mechanisms using present-day methodologies and guidance. By letter dated March 12, 2013 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML13093A260), Exelon Generation Company, LLC (Exelon, the licensee) responded to this request for Three Mile Island Nuclear Station, Unit 1 (Three Mile Island). The licensee subsequently provided a revised Flood Hazard Reevaluation Report by letter dated August 13, 2015 (ADAMS Accession No. ML15225A266). The NRC's review is based on the 2015 report.

By letter dated March 31, 2016 (ADAMS Accession No. ML16091A084), the NRC staff sent the licensee a summary of its review of Three Mile Island'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, because local intense precipitation, failure of dams and onsite water control/structures, and ice-induced flooding at Three Mile Island are not bounded by the plant's current design basis, additional assessments of the flood hazard mechanisms are necessary. The licensee submitted the additional assessment, the Focused Evaluation, by letter dated January 5, 2017 (ADAMS Accession No. ML17006A159). It is currently under review.

The NRC staff has no additional information needs at this time with respect to Exelon's 50.54(f) response related to flooding. This staff assessment closes out the NRC's efforts associated with CAC Nos. MF1113.

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

If you have any questions, please contact me at (301) 415-1056 or by electronic mail at Lauren.Gibson@nrc.gov.

Sincerely,

Lauren Kate Gibson

Lauren K. Gibson, Project Manager
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Docket No. 50-289

Enclosures:
1. Staff Assessment of Flood Hazard Reevaluation Report (Non-Public)
2. Staff Assessment of Flood Hazard Reevaluation Report (Public)

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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

THREE MILE ISLAND NUCLEAR STATION, UNIT 1

DOCKET NO. 50-289

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* (CFR), Section 50.54(f) (hereafter referred to as the "50.54(f) letter"). The request was issued in connection with implementing lessons learned from the 2011 accident at the Fukushima Dai-ichi nuclear power plant as documented in the Near-Term Task Force (NTTF) report (NRC, 2011a). Recommendation 2.1 in that document recommended that the NRC staff issue orders to all licensees to reevaluate seismic and flooding for their sites against current NRC requirements and guidance. Subsequent staff requirements memoranda associated with SECY-11-0124 (NRC, 2011c) and SECY-11-0137 (NRC, 2011d), directed the NRC staff to issue requests for information to licensees pursuant to 10 CFR 50.54(f) to address this recommendation.

Enclosure 2 to the 50.54(f) letter (NRC, 2012a) requested that licensees reevaluate 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 each plant. On May 11, 2012, the NRC staff issued its prioritization of the FHRRs (NRC, 2012b).

By letter dated August 13, 2015, Exelon Generation Company, LLC (Exelon, the licensee) provided the FHRR for Three Mile Island Nuclear Station, Unit 1 (TMI).[1] As part of a site audit, the staff requested additional information from the licensee to supplement the FHRR, which the license provided. The NRC staff issued an Audit Summary Report summarizing additional information obtained during the audit (NRC, 2017b).

On March 31, 2016, the NRC issued an interim staff response (ISR) letter to the licensee (NRC, 2016c). The purpose of the ISR letter is to provide the flood hazard information suitable for the assessment of mitigating strategies developed in response to Order EA-12-049 (NRC, 2012b) and the additional assessments associated with Recommendation 2.1: Flooding. The ISR letter also made reference to this staff assessment, which documents the NRC staff's basis and conclusion. The flood hazard mechanism values presented in the letter's enclosures match the values in this staff assessment without change or alteration.

As mentioned in the ISR letter (NRC, 2016c), the reevaluated flood hazard results for the local intense precipitation (LIP), dam failure and ice-induced flood-causing mechanisms are not

[1] The 2015 FHRR supersedes the report was previously submitted on March 12, 2013 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML13093A260).

bounded by the plant's current design basis (CDB). Consistent with the 50.54(f) letter and amended by the process outlined in COMSECY-15-0019 (NRC, 2015), Japan Lessons-Learned Division (JLD) Interim Staff Guidance (ISG) JLD-ISG-2012-01, Revision 1 (NRC, 2016a) and JLD-ISG-2016-01, Revision 0 (NRC, 2016b), the NRC staff anticipates that the licensee will perform and document a focused evaluation for LIP and associated site drainage that assesses the impact of the LIP hazard on the site and that the licensee will evaluate and implement any necessary programmatic, procedural or plant modifications to address this hazard exceedance. Additionally, for the failure of dams and onsite water control/storage structures and ice-induced flood-causing mechanisms, the NRC staff anticipates that the licensee will submit either (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, 2016c).

Additionally, for any reevaluated flood hazards that are not bounded by the plant's CDB hazard, the licensee was expected to develop flood event duration (FED) parameters and associated effects (AE) parameters. These parameters were used to conduct the mitigating strategies assessment (MSA) and focused evaluation or integrated assessment. By letter dated June 29, 2016, the licensee submitted the MSA (Exelon, 2016). The NRC staff's review of the MSA is documented in a separate staff assessment dated January 10, 2017 (NRC, 2017a). The licensee submitted the Focused Evaluation (FE) by letter dated January 5, 2017 (Exelon, 2017). It is currently under review.

2.0 REGULATORY BACKGROUND

2.1 Applicable Regulatory Requirements

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

Sections 50.34(a)(1), (a)(3), (a)(4), (b)(1), (b)(2), and (b)(4), of 10 CFR, describe the required content of the preliminary and final safety analysis reports, including a discussion of the 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 10 CFR Part 50 states that structures, systems, and components (SSCs) important to safety at nuclear power plants must be designed to withstand the effects of natural phenomena, such as earthquakes, tornados, hurricanes, floods, tsunamis, and seiches without the loss of capability to perform their intended safety functions. The design bases for these SSCs are to reflect appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area. The design bases are also to have sufficient margin to account for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

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

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

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

2.2 Enclosure 2 to the 50.54(f) Letter

Section 50.54(f) of 10 CFR states that a licensee shall at any time before expiration of its license, upon request of the Commission, submit written statements, signed under oath or affirmation, to enable the Commission to determine whether or not the license should be modified, suspended, or revoked. The 50.54(f) letter (NRC, 2012a) requested, in part, that licensees reevaluate the flood-causing mechanisms for their respective sites using present-day methodologies and regulatory guidance used by the NRC for the ESP and COL reviews.

2.2.1 Flood-Causing Mechanisms

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

2.2.2 Associated Effects

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

- Wind waves and runup effects
- Hydrodynamic loading, including debris
- Effects caused by sediment deposition and erosion
- Concurrent site conditions, including adverse weather conditions
- Groundwater ingress
- Other pertinent factors

2.2.3 Combined Effects Flood

The worst flooding at a site that may result from a reasonable combination of individual flooding mechanisms is sometimes referred to as a "combined effects flood". It should also be noted that for the purposes of this staff assessment, the terms "combined effects" and "combined events" are synonyms. Even if some or all of these individual flood-causing mechanisms are less severe than their worst-case occurrence, their combination may still exceed the most severe flooding effects from the worst-case occurrence of any single mechanism described in the 50.54(f) letter (see SRP Section 2.4.2, Areas of Review (NRC, 2007)). Attachment 1 of the 50.54(f) letter describes the "combined effect flood" as defined in American National Standards Institute/American Nuclear Society (ANSI/ANS) 2.8-1992 (ANSI/ANS, 1992) as follows:

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

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

2.2.4 Flood Event Duration

Flood event duration was defined in JLD-ISG-2012-05 (NRC, 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.

2.3 Actions Following the FHRR

For the sites where the reevaluated flood hazard is not bounded by the CDB flood hazard elevation for any 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 were not required to perform an integrated assessment. COMSECY-15-0019 (NRC, 2015b) outlines a revised process for addressing cases in which the reevaluated flood hazard is not bounded by the plant's CDB. The revised process describes an approach in which licensees with LIP hazards exceeding their CDB flood will not be required to complete an integrated assessment, but instead will perform a focused evaluation. As part of the focused evaluation, licensees will assess the impact of the LIP hazard on their sites and then evaluate and implement any necessary programmatic, procedural, or plant modifications to address the hazard exceedance. For other flood hazard mechanisms that exceed the CDB, licensees can assess the impact of these reevaluated hazards on their site by performing either a focused evaluation or a revised integrated assessment (NRC, 2015 and NRC, 2016a).

3.0 TECHNICAL EVALUATION

The NRC staff reviewed the information provided for the flood hazard reevaluation of the TMI, Unit 1 site (Exelon, 2015). 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 TMI FHRR, the licensee made several calculation packages available to the NRC staff. The NRC staff did not directly rely on these calculation packages in its review; they were found only to expand upon and clarify the information provided in the TMI FHRR, and so those calculation packages were not docketed or cited. The NRC staff's review and evaluation are provided below.

3.1 Site Information

The 50.54(f) letter (NRC, 2012a) requested that relevant SSCs important to safety be included in the scope of the hazard reevaluation. The licensee included this pertinent data concerning these SSCs in the FHRR (Exelon, 2015). The NRC staff reviewed and summarized this information as follows in the sections below.

3.1.1 Detailed Site Information

The TMI site is located approximately 2.5 miles south of Middletown, Pennsylvania, on an island in the Susquehanna River. The Susquehanna River narrows upstream of the site before widening to approximately 1.5 miles in the vicinity of the TMI site. The York Haven Dam is located just south (downstream) of the TMI site; the Conowingo Dam is a further 50 miles downstream. The TMI site grade is 304 feet (ft.) on the National Geodetic Vertical Datum of 1929 (NGVD29). Unless otherwise stated, all elevations in this staff assessment are given with respect to NGVD29. The licensee noted that there are four SSCs important to safety below the site grade.

3.1.2 Design-Basis Flood Hazards

The NRC staff noted that the FHRR referred to both the CLB and the CDB. At the NRC staff's request, the licensee stated that the two terms are synonymous (NRC, 2017b). The CDB flood levels area summarized by flood-causing mechanism in Table 3.1-1. The licensee summarized the CDB hazards for the TMI site, of which the Susquehanna River is the principal source of flooding. The design-basis flood elevation for a river flooding event is 313.3 ft. NGVD29 at the Intake Screen and Pump House (ISPH). The probable maximum flood (PMF) was defined by the U.S. Army Corps of Engineers (USACE) at the time of the preliminary safety analysis report in 1967. The PMF was revised in 1969 to include a peak discharge of 1,625,000 cubic feet per second (cfs), which corresponded to a predicted water level of 309 ft. NGVD29. The stage discharge was reevaluated in 2011 and an updated peak water level of 313.3 ft. NGVD29 was identified at the ISPH.

The failure of the upstream [redacted] is the bounding dam failure event in the CDB with a predicted water elevation of less than [redacted] The TMI site would have between 20 and 28 hours of warning time from the failure of the [redacted] to when the flood flows arrive at the TMI site. The CDB also considers downstream dam failures, particularly the [redacted]. Failure of both of these dams would result in a river surface elevation drop to [redacted] however, the TMI site can safely shutdown after this event. The CDB does not address storm surge, seiche, tsunami, ice-induced flooding or channel migration or diversion.

The NRC staff reviewed the information provided in the TMI FHRR (Exelon, 2015) and determined that sufficient information was provided to be responsive to Enclosure 2 of the 50.54(f) letter (NRC, 2012a).

3.1.3 Flood-Related Changes to the Licensing Basis

As discussed in the previous section, the CDB flood elevation for streams and rivers was updated as recently as 2011. This reevaluation used two-dimensional (2D) finite element modeling to simulate PMF hydraulics and develop stage-discharge rating curves. The licensee concluded that the water level at the peak licensing basis event flow of 1,625,000 cfs was 313.3 ft. NGVD29, up from the original licensing basis elevation of 309 ft. NGVD29. The licensee noted that the TMI, Unit 1 flood protection barriers were reevaluated and modified to raise the minimum level of flood protection to elevation 313.5 ft. NGVD29.

Following the Individual Plant Examination of External Events risk assessment process, the licensee procured portable equipment to provide core cooling for events with flood water levels up to 320 ft. NGVD29. The licensee also identified and corrected deficiencies and updated site drawings and plans to reflect plant modifications. The NRC staff reviewed the information provided in the TMI FHRR (Exelon, 2015) and determined that sufficient information was provided to be responsive to Enclosure 2 of the 50.54(f) letter (NRC, 2012a).

3.1.4 Changes to the Watershed and Local Area

The FHRR states that the most significant change in the Susquehanna watershed is the construction of three flood control dams, Tioga, Hammond and Cowanesque, in the upstream watershed in 1979. Changes in land use since license issuance include development and reforestation efforts in formerly agricultural areas. In addition, stormwater management practices such as the Pennsylvania Stormwater Management Act 167 (enacted in 1978) have been implemented throughout the watershed to achieve peak flow reduction. The NRC staff reviewed the information provided in the TMI FHRR (Exelon, 2015) and determined that sufficient information was provided to be responsive to Enclosure 2 of the 50.54(f) letter (NRC, 2012a).

3.1.5 Current Licensing Basis Flood Protection and Pertinent Flood Mitigation Features

The licensee stated that the TMI site is surrounded by an earthen dike at elevation 310 ft. NGVD29 at the north end of the site that gradually slopes down to 304 ft. NGVD29 at the south end. This dike is designed for flooding events with flow rates up to 1,100,000 cfs. Barriers and seals prevent water intrusion into safety-related structures for events up to 313.5 ft. NGVD29. Flood gates and other temporary elements can be installed based on forecasted river elevation or rising river levels. The licensee noted the expanded mitigation capacity for river levels up to 320 ft. NGVD29 is available using the system of portable equipment on site. This was further discussed in the licensee's MSA and the staff's related response. While the presence of the FLEX equipment is a requirement of Order EA-12-049, protecting to the exact flooding level of 320 ft. is not currently a licensing basis requirement. The NRC staff reviewed the information provided in the TMI FHRR (Exelon, 2015) and determined that sufficient information was provided to be responsive to Enclosure 2 of the 50.54(f) letter (NRC, 2012a).

3.1.6 Additional Site Details to Assess the Flood Hazard

The licensee provided model input and output files and associated hydrologic and bathymetric data, which was used by the NRC staff during the review.

3.1.7 Results of Plant Walkdown Activities

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

By letter dated November 19, 2012 (Exelon, 2012), and January 31, 2014 (Exelon, 2014), the licensee submitted the Flooding Walkdown Report for the TMI site. On June 16, 2014 (NRC, 2014), the NRC staff issued its assessment of the Walkdown Report, which documented its review of that licensee's action and concluded that the licensee's implementation of the flooding walkdown methodology met the intent of the 50.54(f) letter.

3.2 <u>Local Intense Precipitation</u>

The licensee reported in its FHRR that the reevaluated flood hazard, including associated effects, for LIP and associated site drainage is based on a stillwater-surface elevation of 304.6 ft. North American Vertical Datum of 1988 (NAVD88) at the Reactor Building, where there is no pathway for water to enter. Among locations with pathways to safety-related structures, the maximum stillwater elevation is 304.5 ft. NAVD88 at the Auxiliary Building, Unit 1, Borated Water Storage Tank Tunnel Sumps (WDL-V-612). Table 4.1-1 provides a complete list of the locations and flood elevations. This flood-causing mechanism is not discussed in the licensee's CDB.

The licensee created a FLO-2D Basic 2009 model to calculate the maximum water surface elevations (WSE) during the LIP storm at the TMI site. FLO-2D is a two-dimensional volume conservation model with a gridded interface that is ideal for rainfall to runoff simulation of unconfined overland flow. The licensee assumed that all the drainage system components (e.g., gravity storm drain systems, culverts, inlets) are non-functional or completely blocked during the LIP event, that the soil is fully saturated and there are no runoff losses, and that the precipitation on building roofs discharges directly to the ground and contributes to the ground surface runoff (following the worst case scenario). The exception to these assumptions is that a 60-in. culvert pipe draining to the river was assumed to be 50 percent blocked because of the large size of the pipe and the minimal expected debris. The licensee assumed the LIP event was non-coincidental with any other flooding events. The NRC staff reviewed all licensee assumptions and concludes that these assumptions are conservative and consistent with guidance.

The licensee considered the 1-hour, 1-mi² probable maximum precipitation (PMP) event as input to the FLO-2D model. As suggested in NUREG/CR-7046 (NRC, 2011e), the licensee identified the 1-hour, 1-mi² PMP event using the National Oceanic and Atmospheric Association (NOAA) Hydrometeorological Report (HMR) 52 (NOAA, 1982). The licensee estimated a total PMP of 17.8 in. for the duration of the 1-hour storm, with the storm intensity peaking in the first 5 minutes of the storm.

The terrain data for the FLO-2D model was determined by the licensee using Light Detection and Ranging (LiDAR) data of the TMI site collected in 2012. Based on estimated elevations from the LiDAR data, the licensee elevated the cells corresponding to buildings and towers to simulate them in the FLO-2D model. Vehicle Barrier Systems (VBS) located throughout the site were represented in the model as levees. The NRC staff noted from aerial imagery that one barrier within the vicinity of the powerblock area was not included in the licensee's model. At the NRC staff's request, the licensee reevaluated their FLO-2D model to include a VBS that had been omitted in the original model. The results showed that the calculated WSEs at doors and other pathways to safety-related structures were insensitive to the inclusion of the additional VBS (NRC, 2017b). The NRC staff reviewed this sensitivity analysis and agrees with the licensee's conclusion.

Other parameters within the FLO-2D model, such as grid cell size and Manning's *n* land cover roughness coefficients were considered reasonable by NRC staff. Model stability values were noted by NRC staff to vary slightly from suggested values within the FLO-2D Basic Data Input Manual. However, NRC staff determined that the deviation from suggested values did not significantly impact the resulting maximum WSE at safety-related facilities of the TMI site.

The NRC staff confirmed the licensee's reevaluation of the hazard from LIP used present-day methodologies and regulatory guidance. The NRC staff also confirmed the licensee's conclusion that the reevaluated flood hazard for LIP was not bounded by the CDB flood hazard. Therefore, the NRC staff expected that the licensee would submit a focused evaluation for LIP and associated site drainage for the TMI site. The licensee submitted the Focused Evaluation, by letter dated January 5, 2017 (Exelon, 2017). It is currently under review.

3.3 Streams and Rivers

The licensee reported in its FHRR that the reevaluated flood hazard for streams and rivers is based on a stillwater surface elevation of 309.9 ft. NGVD29 at the ISPH. Including wind waves and runup results in an elevation of 311.8 ft. NAVD 29 at the ISPH. This flood-causing mechanism is discussed in the licensee's CDB. The CDB PMF elevation for streams and rivers is based on a stillwater surface elevation of 313.3 ft. NGVD29 at the ISPH.

3.3.1 Probable Maximum Flood Alternative Selection

The licensee analyzed the alternatives that combine multiple events as defined in NUREG/CR-7046 (NRC, 2011d) for the PMF from rivers, and determined that a combination of mean monthly base flow; median soil moisture, and 40 percent PMP followed by the main all-season PMP results in the governing PMF at TMI with a peak flow of 1,530,000 cfs. The licensee provided discussions of all of the alternatives, which included analyses of the site-specific PMP using the methods found in HMR 51 (NOAA, 1978) and HMR 52 (NOAA, 1982). The development of the all-season site-specific PMP was reviewed and endorsed by the Federal Energy Regulatory Commission (FERC) Board of Consultants (BOC) for the Conowingo Hydroelectric Project (BOC, 2015). The NRC staff participated as observers of the review process by attending several meetings of the BOC. Based on the review and endorsement of the FERC BOC, the NRC staff found the licensee's development of the all-season site-specific PMP to be acceptable.

3.3.2 Probable Maximum Snowpack and Snowmelt Analysis

For the combination of mean monthly base flow, probable maximum snowpack and 100-year cool-season rainfall, the licensee calculated the probable maximum snowpack using the techniques applied in HMR 42 (U.S. Weather Bureau, 1966) and Buckler (1968). Snowmelt rates for rain-on-snow and rain-free scenarios were computed in accordance with procedures found in EM 1110-2-1406 (USACE, 1998). The NRC staff noted that the FHRR indicated that a record snow-melt event from rain on snow occurred in January 1996; however, it was not clear if this event was the largest of five events discussed in the FHRR or a true record snow-melt event. The licensee stated that of the five events listed in Table 6 of its FHRR, the January 1996 event was the only event with sufficient snowpack depth and density to calibrate the hydrologic model (NRC, 2017b). The NRC staff found this response to be reasonable.

For the combination of mean monthly base flow, 100-year snowpack and cool-season PMP, the licensee spatially distributed the 100-year Snow Water Equivalent over the watershed in accordance with Cornell University's report (Wilks and McKay, 1994) and with snowmelt rates developed in accordance with procedures found in EM 1110-2-1406 (USACE, 1998).

The NRC staff reviewed the snowmelt analysis, noted that the methodology selected was appropriate, and that the procedures were used correctly. The NRC staff verified that the inputs result in a reasonable level of conservatism for snowpack and snowmelt.

3.3.3 Probable Maximum Flood Hydrology

The licensee computed the PMF flow hydrograph at TMI using ArcGIS (Version 10.0), HEC-GeoHMS [Hydrologic Engineering Center – Hydrologic Modeling System] (Version 10.0) and HEC-HMS software (Version 3.5) for the Susquehanna River. The delineation of watersheds was done with data obtained from the U.S. Geological Survey (USGS). Inputs for precipitation and snowmelt are described above in Sections 3.3.1 and 3.3.2, as well as NOAA's National Climate Data Center (NCDC, n.d.). Loss rates were determined from NRCS soil data, while percent impervious data were taken from USGS (USGS, n.d.). The HEC-HMS models were calibrated and validated against historical storm events, including Tropical Storm Lee, Hurricane Ivan, and Hurricane Agnes (Exelon, n.d.). The licensee also used historical storm data to determine the appropriate rainfall-runoff transform and routing parameters. The NRC staff noted that the storm centering information was not provided in the FHRR. In response to the NRC staff's request, the licensee clarified that the storm centering ranged from 191 to 212 degrees (NRC, 2017b).

The NRC staff reviewed the hydrologic analysis and noted that the methodology selected was appropriate and that the procedures were used appropriately. The NRC staff verified that the inputs result in a reasonable level of conservatism for the probable maximum flood hydrology.

3.3.4 Probable Maximum Flood Water Surface Elevations

To derive maximum flood elevations at the site from the PMF flow calculated by the HEC-HMS model, the licensee analyzed dynamic channel routing of the inflow using the HEC-RAS [River Analysis System] hydraulic model (Version 4.1) and RiverFlow2D software. The licensee obtained a maximum stillwater elevation of 309.9 ft. NGVD29 at the ISPH.

The licensee developed the HEC-RAS model for a reach of the Susquehanna River of sufficient length to encompass the entire site. The licensee developed cross sections and floodplain geometries for the Susquehanna River and incorporated bathymetric data from the Federal Emergency Management Agency's effective (1978) HEC-2 hydraulic model. Structures added to the HEC-RAS model include: the East Channel York-Haven Dam, West Channel York-Haven Dam, Shocks Mill Railway Bridge, upstream TMI access bridge, and downstream TMI access bridge. The bridge geometry for the Shocks Mill Railway Bridge was obtained from the 1904 (original bridge construction) through 1972 (reconstruction of center span after Tropical Storm Agnes) as-built plans as provided by Norfolk Southern. The licensee interpreted the bridge geometry for the upstream TMI access bridge from available plans. The downstream TMI access bridge geometry was estimated using aerial photography and using the upstream TMI access bridge as a template for parapet heights and support pier widths. The West and East Channel York-Haven Dams geometries were estimated using available reports. In addition, the geometries of these dams were qualitatively verified through field observation, although no survey was conducted. The licensee stated that the dams cause a low head drop in the channel and are overtopped during high flow events.

The licensee used the HEC-HMS results for the upstream boundary conditions for the HEC-RAS model. A stage-discharge curve from the Marietta Gage Station was used for the downstream boundary condition. The NRC staff verified the HEC-RAS model setup, including geometries and flow inputs. The NRC staff reviewed geometry files including a review of the cross sections, structures, and the stream delineation. The NRC staff executed the model to ensure no modeling errors appeared. The licensee calibrated the HEC-RAS model with the historical event Tropical Storm Agnes (1972) using high water marks. The FHRR states that the calibration focused on achieving the historical peak flood elevation at TMI by adjusting the Manning's n-value.

Because of the complex flow patterns in the vicinity of TMI, a two-dimensional flow model was created using RiverFlow2D. The RiverFlow2D model was used to supplement the HEC-RAS 1D model to more accurately predict flood elevations at the TMI site. The RiverFlow2D model used a stage-discharge relationship, computed by the HEC-RAS model, as the downstream boundary conditions. The final water surface elevations reported in the FHRR are based on the RiverFlow2D model.

Based on review of the licensee's information provided for the PMF analysis, the NRC staff agree with the licensee's reevaluated stillwater PMF elevation for flooding from streams and rivers. The NRC staff confirms the licensee's conclusion that the reevaluated hazard for flooding from rivers and streams is bounded by the CDB. Therefore, 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 the FHRR that the reevaluated flood hazard for failure of dams and on-site water control or storage structures is based on a stillwater-surface elevation that ranges from [redacted] NGVD29 for seismic dam failure at the ISPH up to [redacted] NGVD29 for hydrologic dam failure at the north end of dike Number 2. This flood-causing mechanism is discussed in the licensee's CDB. The CDB probable maximum flood elevation for failure of dams and onsite water control or storage structures is based on a stillwater-surface elevation of [redacted] NGVD29 at the ISPH. Wind and wave runup is not addressed in the CDB.

3.4.1 Critical Dam Evaluation and Selection

The licensee reported that the USACE National Inventory of Dams Database (NID) shows 708 dams in the Susquehanna River watershed upstream of TMI. Of the 708 dams, 279 were identified as inconsequential and screened from further evaluation using JLD-ISG-2013-01 (NRC, 2013b). Ultimately, the licensee individually modeled 15 dams and grouped the remaining dams into 34 "hypothetical" dams. Figure 3.4.1-1 shows the modeled dams. The licensee used methodologies presented by Froehlich (2008) and Xu and Zhang (2009) to develop breach parameters for the dams for use in HEC-HMS.

3.4.2 Upstream Dam Failure Mechanism Summary

The licensee evaluated dam failures for two failure mechanisms, hydrologic and seismically induced. Although the licensee did not address a sunny day event, the NRC staff agree with the licensee that the sunny day failure mechanism would be bounded by the seismically induced dam failure.

3.4.3 Hydrologic Dam Failure Analysis

To identify the worst flooding at the site, the licensee used an initial water surface elevation in the reservoirs of 0.1 ft. below the emergency spillway crest. The licensee then used the governing All-Season Site-Specific PMP values as discussed in Section 3.3.1 as input to the overtopping dam failure HEC-HMS models. The licensee first set the trigger for the composite dams to fail at the top of dam, then routed the flow into the individual dams to determine the timing of maximum water surface and volume in the individual dams. The licensee then set the individual dams upstream of TMI to breach at the time of maximum volume in the reservoir. Breach parameters were estimated based on Froehlich (2008) and Xu and Zhang (2009). The methods were compared for each dam, and the more conservative of the results were used in the HEC-HMS modeling.

The resulting discharges from the HEC-HMS dam break modeling were used as inputs to two hydraulic models, HEC-RAS and RiverFlow2D. The licensee reported the peak water surface elevations for the Governing PMF with overtopping dam failure at three locations along TMI. At the ISPH, the peak stillwater elevation was reported as [redacted] NGVD29.

The NRC staff noted that some bridge structural geometry information were not known and had to be estimated. The licensee stated that the only bridge with unknown geometry was [redacted] downstream of the site and would be overtopped during the reevaluated flood, causing a minimal impact on the water surface elevation (NRC, 2017b). The NRC staff reviewed the hydraulic model and agrees with the licensee's conclusion.

Additionally, the NRC staff noted that the rating curve presented in the FHRR did not account for hysteresis. The licensee agreed, but stated that the change in discharge over time would not significantly affect the stage discharge relationship (NRC, 2017b). The NRC staff reviewed the analysis and agrees with the licensee's conclusion.

The NRC staff reviewed the HEC-HMS, HEC-RAS, and RiverFlow2D models and concluded that the model parameters, modeling of structures, and roughness coefficients used for hydrologic dam failure analysis were reasonable and appropriate for the modeled conditions. Hence, the NRC staff concluded that the modeling results for hydrologic dam failure were reasonable and appropriate.

3.4.4 Seismic Upstream Dam Failure

For upstream seismic dam failure, the licensee estimated the peak discharge at TMI using HEC-HMS for simultaneous failure of all upstream dams due to a seismic event in conjunction with the lower of the 50 percent PMP or the 500-year rainfall, in accordance with NUREG/CR-7046, Section 3.9 and Appendix H.2. The licensee ran multiple simulations with all dams failing simultaneously to determine the critical peak flow rate associated with the limiting dam failure event. The timing of the simultaneous failures was varied from time step [redacted] to up to [redacted] after the start of the rainfall to bracket the bounding breach time configuration. Breach parameters were estimated based on Froehlich (2008) and Xu and Zhang (2009). The methods were compared for each dam, and the more conservative of the results were used in the HEC-HMS modeling.

The resulting discharges from the HEC-HMS dam break modeling were used as inputs to two hydraulic models, HEC-RAS and RiverFlow2D. The licensee reported the peak water surface elevations for the seismically induced failure at three locations along TMI. At the ISPH, the peak stillwater elevation was reported as [redacted] NGVD29. This failure mechanism is bounded by the hydrologic failure.

The NRC staff reviewed the HEC-HMS, HEC-RAS, and RiverFlow2D models and concluded that the model parameters, modeling of structures, and roughness coefficients used for upstream seismic dam failure were reasonable and appropriate for the modeled conditions. Hence, the NRC staff concluded that the modeling results for upstream seismic dam failure were reasonable and appropriate.

3.4.5 Upstream Dam Failure Timing and Duration

As discussed above in Sections 3.4.3 and 3.4.4, the NRC staff evaluated the timing of the upstream dam failures, as modeled by the licensee, to produce the maximum peak discharge at TMI. The NRC staff reviewed the timing analyses by reviewing the hydrographs from each alternative analysis (hydrologic and seismic) and concluded that the evaluation of timing and duration was reasonable.

3.4.6 Conclusion

The NRC staff reviewed the licensee's methodology for the PMF analysis and concludes that the methods are appropriate for the purposes of the 50.54(f) letter. The NRC staff confirmed the licensee's conclusion that the reevaluated flood hazard for failure of dams and onsite water control structure is not bounded by the CDB flood hazard for failure of dams and onsite water control structure. Therefore, the NRC staff expected that the licensee would submit a focused evaluation for failure of dams and onsite water control structures for the TMI site. The licensee submitted the FE by letter dated January 5, 2017 (Exelon, 2017). It is currently under review.

The NRC staff acknowledges that the licensee considered hydrologic dam failure as part of the reevaluated probable maximum flood discussed in section 3.3 above, as described in Sections 4.b and 5 of the FHRR (Exelon, 2015).

3.5 Storm Surge

The licensee reported that the reevaluated hazard for storm surge-related flooding effects are not applicable to the TMI site (Exelon, 2015). This flood-causing mechanism is not discussed in the licensee's CDB.

The licensee noted that the TMI site is approximately 53 miles upstream from the head-of-tide of the Susquehanna River and is upstream of Conowingo and Safe Harbor Dams. Therefore, the licensee did not consider storm surge to be an applicable flood hazard at the TMI site. The NRC staff reviewed the information provided by the licensee and agrees that a storm surge event at the TMI site is not likely due to the distance from the Chesapeake Bay and the presence of the two downstream dams.

The NRC staff confirmed the licensee's conclusion that the storm surge flood-causing mechanism could not inundate the TMI site. Therefore, the NRC staff determined that flooding from storm surge does not need to be analyzed in a focused evaluation or a revised integrated assessment.

3.6 Seiche

The licensee reported that the reevaluated hazard for seiche-related flooding effects are not applicable to the TMI site (Exelon, 2015). This flood-causing mechanism is not discussed in the licensee's CDB.

The licensee noted that because the Susquehanna River is not an enclosed or semi-enclosed water body seiche is not an applicable flood-causing mechanism at the TMI site. The NRC staff reviewed the information provided by the licensee, and agrees that a seiche event at the TMI site is not likely due to the inland location.

The NRC staff confirmed the licensee's conclusion that the seiche flood-causing mechanism could not inundate the TMI site. Therefore, the NRC staff determined that flooding from seiche does not need to be analyzed in a focused evaluation or a revised integrated assessment.

3.7 Tsunami

The licensee reported that the reevaluated hazard for tsunami-related flooding effects are not applicable to the TMI site (Exelon, 2015). This flood-causing mechanism is not discussed in the CDB.

The licensee noted that the 59-mile distance from the TMI site to the Chesapeake Bay, in combination with the elevation difference, topography, and downstream dams, make it unlikely for the Susquehanna River to propagate a tsunami generated in the Chesapeake Bay. Therefore, the licensee concluded that tsunami is not an applicable flood-causing mechanism at the TMI site.

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

3.8 Ice-Induced Flooding

The licensee reported that the reevaluated flood hazard for ice-induced flooding is bounded by the reevaluated dam failure flood-causing mechanism elevation of [redacted] NGVD29. This flood-causing mechanism is not discussed in the CDB.

The licensee performed an evaluation of ice-induced flooding mechanisms in accordance with Section 3.7 of NUREG/CR-7046 (NRC, 2011e). The licensee used historic ice jam information in the vicinity of the TMI to determine the peak discharge from the most severe ice jam event and compared it to the peak discharge determined from other evaluated flood hazards. The licensee determined that the peak discharge used for the design of the dike protecting the TMI site is higher than the equivalent peak discharge from an historic ice jam event. Further hydraulic modeling of a potential ice jam near the TMI site using HEC-RAS showed that the ice jam event was bounded by the seismic dam failure scenario and thus no further analysis was required. The NRC staff reviewed the HEC-RAS models and concluded that the model parameters, modeling of structures, and roughness coefficients were reasonable and appropriate for the modeled conditions. Hence, the NRC staff concluded that the modeling results were reasonable and appropriate.

The licensee used historical records to determine the most severe historical event in the site vicinity. Following the guidance in NUREG/CR-7046, the licensee compared maximum water surface elevations from the most severe ice jam event to the peak dam failure event and determined that the dam failure event was the bounding hazard. The licensee also consulted the USACE Ice Engineering Group at Cold Regions Research and Engineering Laboratory (CRREL) to identify 28 upstream and 8 downstream ice jam events. The most severe ice jam event occurred in 1996 resulting in a peak discharge of 588,000 cfs, which the licensee noted is below the peak design flow of the flood protection dike at the TMI site. Therefore, the licensee concluded that the reevaluated hazard for ice-induced flooding is bounded by the dam failure flood-causing mechanism which has a peak discharge of 1,225,000 cfs. See Section 3.4 for additional discussion.

The NRC staff reviewed the licensee's findings in the TMI FHRR and confirmed the licensee's conclusion that the maximum water surface elevation for ice-induced flooding is bounded by the seismic dam failure event, but is not bounded by the CDB. Therefore, the NRC staff expected that the licensee would submit a focused evaluation or revised integrated assessment for ice-induced flooding. The licensee submitted the FE by letter dated January 5, 2017 (Exelon, 2017). It is currently under review.

3.9 Channel Migrations or Diversions

The licensee reported in the TMI FHRR that the reevaluated hazard for channel migrations and diversions is not a significant contributor to flooding at the TMI site (Exelon, 2015). This flood-causing mechanism is not discussed in the CDB.

The licensee consulted historical records and topographic maps to determine whether the Susquehanna River has a tendency to meander near the TMI site. The licensee identified several flooding events, which may have resulted in channel alterations, but observed only minimal visible alterations to the channel. Although the licensee noted areas of sedimentation and aggregation adjacent to the site, these sediment transport processes have not caused channel migration or diversion. Therefore, the licensee determined that flooding from channel migration or diversion is not a significant contributor to flood hazards at the TMI site.

The NRC staff reviewed historical records and topographic maps, as well as the topography of the Susquehanna River in the TMI site vicinity, and determined that there is no evidence of channel migration or diversion that could affect the site. The NRC staff reviewed the information provided by the licensee and confirmed the licensee's conclusion that flooding from channel migrations or diversions is not a plausible flood-causing mechanism at the TMI site. Therefore, the NRC staff determined that flooding from channel migrations or diversions does not need to be analyzed in a focused evaluation or a revised integrated assessment.

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

4.1 Reevaluated Flood Elevation for Hazards Not Bounded by the CDB

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

The NRC staff anticipated the licensee would submit an FE for LIP and either a focused evaluation or revised integrated assessment for dam failure and ice-induced flooding. The licensee submitted the FE by letter dated January 5, 2017 (Exelon, 2017). It is currently under review.

4.2 Flood Event Duration for Hazards Not Bounded by the CDB

The NRC staff reviewed information provided in Exelon's 50.54(f) response (Exelon, 2015) regarding the FED parameters for flood hazards not bounded by the CDB. The FED parameters for the flood-causing mechanisms not bounded by the CDB are summarized in Table 4.2-1.

The licensee did not provide the FED parameters for LIP or ice-induced flooding in the FHRR. However, the licensee provided FED parameters for the dam failure flood-causing mechanism. The NRC staff reviewed the FED parameters provided by the licensee's response (Exelon, 2015) and, as documented in the MSA staff assessment, determined that they are reasonable for use in future assessments of plant response (NRC, 2017a).

The licensee developed FED parameters to conduct its MSA. As noted in Table 4.2-1, the licensee stated that FED parameters are not applicable to the ice-induced flood-causing mechanism because it is bounded by the dam failure flood-causing mechanism. The MSA was submitted on June 29, 2016 (Exelon, 2016). The NRC staff's assessment of the MSA and FED parameters was issued on January 10, 2017 (NRC, 2017a).

4.3 Associated Effects for Hazards Not Bounded by the CDB

The NRC staff reviewed information provided in Exelon's 50.54(f) response (Exelon, 2015) regarding parameters for flood hazards not bounded by the CDB.

The licensee did not provide associated effects parameters in the FHRR. By letter dated June 29, 2016, the licensee submitted its MSA (Exelon, 2016), which included the AE parameters for LIP, dam failure, and ice-induced flooding. These AE parameters are provided in Table 4.3-1 of this staff assessment. Notably, the licensee determined that AE parameters for ice-induced flooding were not required or applicable since the ice-induced mechanism is bounded by the dam failure mechanism. The NRC staff's assessment of the MSA and AE parameters was issued on January 10, 2017 (NRC, 2017a), and concluded that the AE parameters were determined consistent with Appendix G of NEI 12-06, Revision 2 (NEI, 2015).

4.4 Conclusion

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

5.0 CONCLUSION

The NRC staff reviewed the information provided for the reevaluated flood-causing mechanisms for TMI, Unit 1. Based on the review of the available information provided in Exelon's 50.54(f) response (Exelon, 2015), the NRC staff concludes that the licensee conducted the hazard reevaluation using present-day methodologies and regulatory guidance used by the NRC staff in connection with ESP and COL reviews.

Based upon the preceding analysis, the NRC staff confirmed that the licensee responded appropriately to Enclosure 2, Required Response 2, of the 50.54(f) letter, dated March 12, 2012. In reaching this determination, the NRC staff confirmed the licensee's conclusions that: (1) the reevaluated flood hazard results for LIP, failure of dams and onsite water control structures, and ice-induced flooding are not bounded by the CDB flood hazard; (2) additional assessments of plant response would be performed for LIP, failure of dams and onsite water control structures and ice-induced flooding; and (3) the reevaluated flood-causing mechanism information is appropriate input to the additional assessments of plant response as described in the 50.54(f) letter and COMSECY-15-0019 (NRC, 2015a) and associated guidance. The NRC staff has no additional information needs at this time with respect to Exelon's 50.54(f) response.

6.0 REFERENCES

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

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

FLOOD-CAUSING MECHANISM	STANDARD REVIEW PLAN (SRP) SECTION(S) AND/OR 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 3.0-1. Summary of Controlling Flood-Causing Mechanism at the Three Mile Island site.

REEVALUATED FLOOD-CAUSING MECHANISMS AND ASSOCIATED EFFECTS THAT MAY EXCEED THE POWERBLOCK ELEVATION, 304 ft.	WSE (NGVD29)
Local Intense Precipitation and Associated Drainage	305.4 ft. NGVD29
Failure of Dams and Onsite Water Control/Storage Structures	[redacted] NGVD29
Ice-Induced	Bounded by CDB for dam failure

Table 3.1-1 – Current Design Basis Flood Hazards for Use in the MSA

Mechanism	Stillwater Elevation	Waves/Runup	Design-Basis (DB) Hazard Elevation	Reference
Local Intense Precipitation	Not included in DB	Not included in DB	Not included in DB	FHRR Section 3b1
Streams and Rivers	313.3 ft. NGVD29	Not applicable	313.3 ft. NGVD29	FHRR Section 3b2
Failure of Dams and Onsite Water Control/Storage Structures	[redacted] NGVD29	Not applicable	[redacted] NGVD29	FHRR Section 3b3
Storm Surge	Not included in DB	Not included in DB	Not included in DB	FHRR Section 3b4
Seiche	Not included in DB	Not included in DB	Not included in DB	FHRR Section 3b5
Tsunami	Not included in DB	Not included in DB	Not included in DB	FHRR Section 3b6
Ice-Induced Flooding	Not included in DB	Not included in DB	Not included in DB	FHRR Section 3b7
Channel Migrations/Diversions	Not included in DB	Not included in DB	Not included in DB	FHRR Section 3b8

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

Mechanism	Stillwater Elevation	Waves/Runup	Reevaluated Hazard Elevation	Reference
Local Intense Precipitation				
Air Intake Pagoda & tunnel	305.2 ft. NGVD29	Minimal	305.2 ft. NGVD29	FHRR Section 4a & Table 3
Auxiliary Building, Unit 1 – BSWT Tunnel Sumps	305.3 ft. NGVD29	Minimal	305.3 ft. NGVD29	FHRR Section 4a & Table 3
Auxiliary Building, Unit 1 – Entrance on South Wall	305.2 ft. NGVD29	Minimal	305.2 ft. NGVD29	FHRR Section 4a & Table 3
Control Building, Unit 1 – Entrance on North Wall	305.2 ft. NGVD29	Minimal	305.2 ft. NGVD29	FHRR Section 4a & Table 3
Control Building, Unit 1 – Entrance on Northeast Wall	305.2 ft. NGVD29	Minimal	305.2 ft. NGVD29	FHRR Section 4a & Table 3
Control Building, Unit 1 – Turbine Building Drains	305.2 ft. NGVD29	Minimal	305.2 ft. NGVD29	FHRR Section 4a & Table 3
Diesel Generating Building – Entrance on North Wall	305.1 ft. NGVD29	Minimal	305.1 ft. NGVD29	FHRR Section 4a & Table 3
Diesel Generating Building – Entrance on East Wall	305.2 ft. NGVD29	Minimal	305.2 ft. NGVD29	FHRR Section 4a & Table 3
Fuel Handling Building, Unit 1 – Entrance on South Wall	305.2 ft. NGVD29	Minimal	305.2 ft. NGVD29	FHRR Section 4a & Table 3
Fuel Handling Building, Unit 1 – Entrance on West Wall	305.2 ft. NGVD29	Minimal	305.2 ft. NGVD29	FHRR Section 4a & Table 3
Fuel Handling Building, Unit 1 – Turbine Building Drains	305.2 ft. NGVD29	Minimal	305.2 ft. NGVD29	FHRR Section 4a & Table 3

Intake Screen & Pump House, Unit 1	305.1 ft. NGVD29	Minimal	305.1 ft. NGVD29	FHRR Section 4a & Table 3
Reactor Building Unit 1	305.4 ft. NGVD29	Minimal	305.4 ft. NGVD29	FHRR Section 4a & Table 3
Failure of Dams and Onsite Water Control/Storage Structures				
Seismic Dam Failure – Intake Screen and Pump House	[redacted] NGVD29	Not applicable	[redacted] NGVD29	FHRR Section 4b2 (Table 16)
Seismic Dam Failure – North End of the Dike	[redacted] NGVD29	Not applicable	[redacted] NGVD29	FHRR Section 4b2 (Table 16)
Seismic Dam Failure – South End of the Dike	[redacted] NGVD29	Not applicable	[redacted] NGVD29	FHRR Section 4b2 (Table 16)
Hydrologic Dam Failure – Intake Screen and Pumphouse (#1)	[redacted] NGVD29	Not applicable	[redacted] NGVD29	FHRR Section 4b3 (Table 17)
Hydrologic Dam Failure – North End of Dike (#2)	[redacted] NGVD29	Not applicable	[redacted] NGVD29	FHRR Section 4b3 (Table 17)
Hydrologic Dam Failure – South End of Dike (#3)	[redacted] NGVD29	Not applicable	[redacted] NGVD29	FHRR Section 4b3 (Table 17)
Ice-Induced Flooding				
Seismic Dam Failure – Intake Screen and Pump House	[redacted] NGVD29	Not applicable	[redacted] NGVD29	FHRR Section 4f & Response to Information Need 15

Note 1: The licensee is expected to develop flood event duration parameters and applicable flood associated effects to conduct the MSA. The staff will evaluate the flood event duration parameters (including warning time and period of inundation) and flood associated effects during its review of the MSA.
Note 2: Reevaluated hazard mechanisms bounded by the CDB are not included in this table.
Note 3: Reported values are rounded to the nearest one-tenth of a foot.
Note 4: FHRR reported ice-induced flooding is bounded by the seismically induced dam failure hazard. Therefore, the maximum water surface elevation reported in this table for this ice-induced flooding is the same as for seismically induced dam failure.

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

FLOOD-CAUSING MECHANISM	TIME AVAILABLE FOR PREPARATION FOR FLOOD EVENT	DURATION OF INUNDATION OF SITE	TIME FOR FLOOD WATER TO RECEDE FROM SITE
Local Intense Precipitation and Associated Drainage (Unit 1)	No Appreciable Warning Time[1]	0 ~ 0.8 h	Can be obtained values from LIP model output (Exelon, 2016)
Failure of Dams and Onsite Water Control/Structures	105.4 h – warning time 37.1 h – preparation time	37.7 h	8 h
Ice-Induced Flooding[2]	Not applicable	Not applicable	Not applicable

Source: (Exelon, 2015 and 2016)
Notes:
[1] The licensee states that an LIP event has no appreciable warning time except those provided by a weather forecast (Exelon, 2015), thus no warning time for this event was assumed (Exelon, 2016).
[2] FED parameters for ice-induced flooding are not applicable because the reevaluated flood level for this event is bounded by that for dam failure mechanism. (Exelon, 2016).

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

	FLOODING MECHANISM		
Associated Effects Parameter	**Local Intense Precipitation and Associated Drainage**	**Dam Failure**	**Ice-Induced[1]**
Hydrodynamic loading at plant grade	Minimal	At Air Intake, 531 psf for hydrostatic pressure, and 104 psf for hydrodynamic pressure (Exelon, 2015, Table 23)	Not Applicable
Debris loading at plant grade	No Impact	At ISPH West Exterior Wall, 9,580 lb for log load and 2,874, 000 lb for barge load (Exelon, 2015, Tables 24 and 25)	Not Applicable
Sediment loading at plant grade	No Impact	Minimal	Not Applicable
Sediment deposition and erosion	No Impact	Minimal	Not Applicable
Concurrent conditions, including adverse weather	No Impact	No Impact	Not Applicable
Groundwater ingress	No Impact	No Impact	Not Applicable
Other pertinent factors (e.g., waterborne projectiles)	No Impact	No Impact	Not Applicable

Source: Exelon (2015), Exelon (2016)
[1] AE parameters for ice-induced flooding are not provided because the reevaluated flood level for this event is bounded by that for the dam failure mechanism.

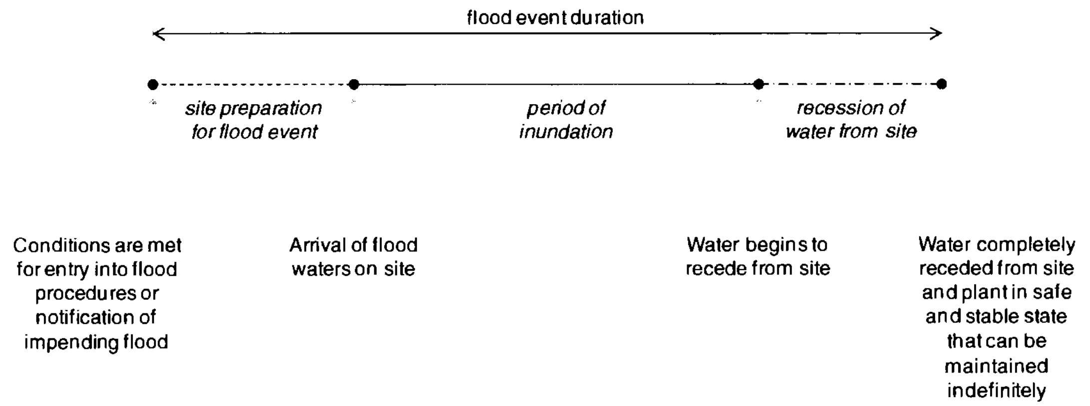

Figure 2.2-1. Flood Event Duration (NRC JLD-ISG-2012-05, Figure 6)

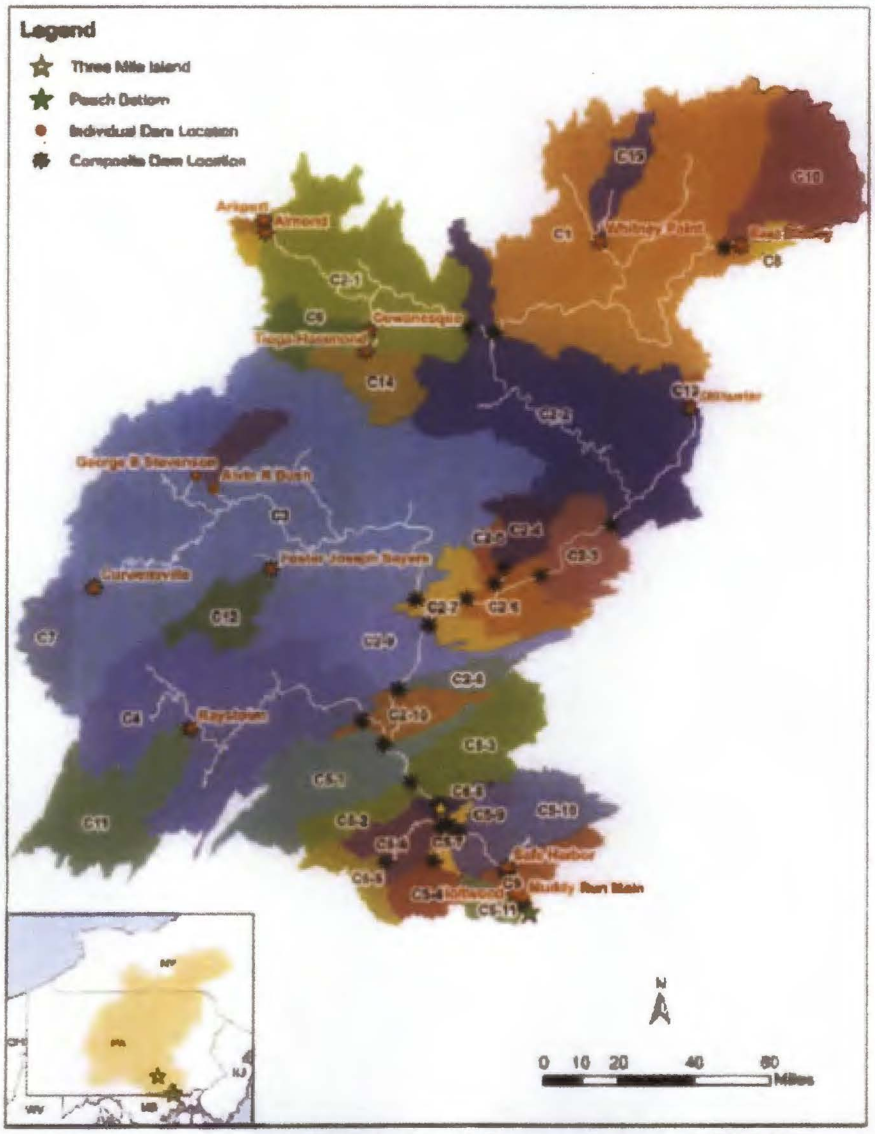

Figure 3.4.1-1 – Upstream Modeled and Grouped Dams (FHRR Figure 26)

SUBJECT: THREE MILE ISLAND NUCLEAR STATION, UNIT 1 – STAFF ASSESSMENT OF RESPONSE TO 10 CFR 50.54(f) INFORMATION REQUEST – FLOOD-CAUSING MECHANISM REEVALUATION DATED November 2, 2017

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