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

March 31, 2015

Mr. Bryan Hanson
Senior Vice President
Exelon Generation Company, LLC
President and Chief Nuclear Office (CNO)
Exelon Nuclear
4300 Winfield Road
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SUBJECT: DRESDEN NUCLEAR POWER STATION, UNITS 2 AND 3 – STAFF ASSESSMENT OF RESPONSE TO 10 CFR 50.54(f) INFORMATION REQUEST – FLOOD-CAUSING MECHANISM REEVALUATION (TAC NOS. MF1795 AND MF1796)

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 10, 2013 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML13135A120), Exelon Generation Corporation, LLC responded to this request for Dresden Nuclear Power Station, Units 2 and 3. In response to NRC staff questions, this response was supplemented by letter dated May 19, 2014 (ADAMS Accession No. ML15092A821).

The NRC staff has reviewed the information provided and, as documented in the enclosed staff assessment, determined that you provided sufficient information in response to the 50.54(f) letter. This closes out the NRC's efforts associated with TAC Nos. MF1795 and MF1796.

If you have any questions, please contact me at (301) 415-2915 or e-mail at Victor.Hall@nrc.gov.

Sincerely,

Victor E Hall

Victor Hall, Senior Project Manager
Hazards Management Branch
Japan Lessons-Learned Division
Office of Nuclear Reactor Regulation

Docket Nos. 50-237 and 50-249

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

RELATED TO THE FUKUSHIMA DAI-ICHI NUCLEAR POWER PLANT ACCIDENT

DRESDEN NUCLEAR POWER STATION, UNITS 2 AND 3

DOCKET NOS. 50-237 AND 50-249

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 license" (hereafter referred to as the 50.54(f) letter). The request was issued in connection with implementing lessons-learned from the 2011 accident at the Fukushima Dai-ichi nuclear power plant as documented in The Near-Term Task Force (NTTF) Review of Insights from the Fukushima Dai-ichi Accident (NRC, 2011b). 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 Commission Papers SECY-11-0124 (NRC, 2011b) and SECY-11-0137 (NRC, 2011c), instructed the NRC staff to issue requests for information to licensees pursuant to 10 CFR 50.54(f).

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

If the reevaluated hazard for all flood-causing mechanisms is not bounded by the current plant design-basis flood hazard, an Integrated Assessment will be necessary. The FHRR and the responses to the associated Requests for Additional Information (RAIs) will provide the hazard input necessary to complete the Integrated Assessment report, as requested in Enclosure 2 of the 50.54(f) letter.

By letter dated May 10, 2013 (Kaegi, 2013), Exelon Generation Corporation, LLC (Exelon, the licensee) provided the FHRR (Exelon, 2013a) for Dresden Nuclear Power Station, Units 2 and 3 (Dresden or DNPS), which included interim actions that the licensee identified and committed to. The NRC staff issued RAIs to the licensee by letter dated April 9, 2014 (NRC, 2014a). The licensee responded to the RAIs by letter dated May 19, 2014 (Barstow, 2014b).

Because a reevaluated flood-causing mechanism is not bounded by the current plant-specific design-basis hazard, the staff anticipates submittal of an Integrated Assessment by the licensee. The staff will prepare an additional staff assessment report to document its review of the Integrated Assessment.

The licensee submitted a separate flooding walkdown report in response to NTTF Recommendation 2.3 (Kaegi, 2012). The staff prepared a separate staff assessment report to document its review of the licensee's flooding walkdown report (NRC, 2014b).

2.0 REGULATORY BACKGROUND

2.1 Applicable Regulatory Requirements

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

Section 50.34(a)(1), (a)(3), (a)(4), (b)(1), (b)(2), and (b)(4), of 10 CFR, describes the required content of the preliminary and final safety analysis reports (FSARs), 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 FSAR.

Section 50.54(f) of 10 CFR states that a licensee shall at any time before expiration of its license, upon request of the Commission, submit written statements, signed under oath or affirmation, to enable the Commission to determine whether or not the license should be modified, suspended, or revoked. The 50.54(f) letter requested 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.

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 for 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 an analysis (based on calculation or 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" 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 FSAR. The licensee's commitments made in docketed licensing correspondence and remain in effect are also considered part of the current licensing basis.

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 includes 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

The 50.54(f) letter requests all power reactor licensees and construction permit holders reevaluate all external flooding-causing mechanisms at each site. The reevaluation should apply present-day methods and regulatory guidance that are used by the NRC staff to conduct ESP and COL reviews. This includes current techniques, software, and methods used in present-day standard engineering practice. If the reevaluated flood-causing mechanisms are not bounded by the current plant design-basis flood hazard, an Integrated Assessment will be necessary.

2.2.1 Flood-Causing Mechanisms

Attachment 1 to NTTF Recommendation 2.1, Flooding (Enclosure 2 of the 50.54(f) letter) discusses flood-causing mechanisms for the licensee to address in the FHRR. Table 2.2.1-1 lists the flood-causing mechanisms the licensee should consider. Table 2.2.1-1 also lists the corresponding Standard Review Plan (SRP) (NRC, 2007) sections and applicable interim staff guidance containing acceptance criteria and review procedures. The licensee should incorporate and report associated effects per Japan Lessons-Learned Directorate (JLD) Interim Staff Guidance (ISG) JLD-ISG-2012-05 (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 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 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 in the 50.54(f) letter. (See SRP Section 2.4.2, Area of Review 9 (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,[1] 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) and SRP Section 2.4.2, Areas of Review 9 (NRC, 2007), then the staff will document and report the result as part of one of the hazard sections. An example of a situation where this may occur is flooding at a riverine site located where the river enters the ocean. For this site, storm surge and river flooding should be plausibly combined.

2.2.4 Flood Event Duration

Flood event duration was defined in the ISG for the Integrated Assessment for external flooding, JLD-ISG-2012-05 (NRC, 2012c), as the length of time during which the flood event affects the

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[1] For the purposes of this Staff Assessment, the terms “combined effects” and “combined events” are synonyms.

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 2.2.4-1 illustrates flood event duration.

2.2.5 Actions Following the FHRR

For the sites where the reevaluated probable maximum flood elevation is not bounded by the current design-basis probable maximum flood elevation for all flood-causing mechanisms, the 50.54(f) letter 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 subsequent to the FHRR to (a) evaluate the effectiveness of the current licensing basis (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 current design-basis flood hazard for all flood-causing mechanisms at the site, licensees are not required to perform an Integrated Assessment at this time.

3.0 TECHNICAL EVALUATION

The NRC staff reviewed the information provided for the flood hazard reevaluation of Dresden , Units 2 and 3. 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. The staff's review and evaluation is provided below.

The licensee's flood hazard reevaluation studies were conducted using conventional units of measure. In this report, the conventional measurements are followed by the equivalent measurement in metric units. Because the conversion to metric units may involve loss of precision, the measurement in conventional units is definitive.

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. The staff relied directly on some of these calculation packages in its review; these calculation packages are docketed, and are cited, as appropriate, in the discussion below. 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 requested additional information from the licensee to supplement the FHRR. The licensee provided this additional information by letter and revised local intense precipitation

(LIP) analysis, both dated May 19, 2014 (Barstow, 2014b and Exelon, 2014), which is discussed below.

All elevations in this Staff Assessment are given with respect to the National Geodetic Vertical Datum of 1929 (NGVD29). The licensee's flood hazard reevaluation studies were mostly conducted using National Geodetic Vertical Datum of 1929 (NGVD29), and the design-basis flood hazard information was developed using mean sea level, which the licensee evaluated to be equivalent to NGVD29.

The site grade at the powerblock is elevation 517.0 ft (157.6 m). Table 3.0-2 provides the summary of controlling reevaluated flood-causing mechanisms, including associated effects, the licensee computed to be higher than the powerblock elevation.

3.1 Site Information

The 50.54(f) letter includes the SSCs important to safety, and the Ultimate Heat Sink, in the scope of the hazard reevaluation. Per the 50.54(f) letter, Enclosure 2, Requested Information, Hazard Reevaluation Report, Item a, the licensee included pertinent data concerning these SSCs in the FHRR.

3.1.1 Detailed Site Information

The DNPS site is located on the south bank of the confluence of the Des Plaines and Kankakee Rivers that forms the Illinois River. The site encompasses 29 acres (117,358 m^2). The site is just upstream of the United States Army Corps of Engineers (USACE) Dresden Island Lock and Dam. The design plant grade is at elevation 517.0 ft (157.6 m) and the finished floor elevation of both Units 2 and 3 is 517.5 ft (157.7 m). The lowest elevation hydraulically connected to safety-related equipment is 509.0 ft (155.1 m) in the Crib House.

The DNPS site relies on the flood emergency procedures to prevent the loss of safe plant control during the probable maximum flood (PMF) event and mitigate the effects of the PMF event. The licensee's FHRR states that the PMF would result in a peak stillwater elevation of 524.8 ft (160.0 m) at the site and wave runup coincident to the PMF would increase the maximum water surface elevation to 529.0 ft (161.2 m). Both predicted water surface elevations are higher than the design plant grade and the lowest opening hydraulically connected to safety-related equipment.

3.1.2 Design-Basis Flood Hazards

The current design-basis flood levels are summarized by flood-causing mechanism in Table 3.1.2-1. The maximum current design-basis flood elevation at the DNPS site is elevation 528.0 ft (160.9 m), which includes wave runup (Exelon, 2013a).

The design-basis flood from the probable maximum flood is discussed in both the licensee's FHRR (Exelon, 2013a) and the LIP evaluation report (Exelon, 2013b). The FHRR states that the maximum peak stillwater elevation during a PMF is 525 ft (160.0 m), while the LIP evaluation report states an elevation of 524.5 ft (159.9 m) at the site based on the Franklin

Research Center (FRC) Technical Evaluation Report (TER) (FRC, 1982 associated with the Systematic Evaluation Program. Staff requested a clarification regarding the PMF maximum stillwater elevation in RAI 1 (NRC, 2014a).

In response to RAI 1 (Barstow, 2014b), the licensee stated that the FRC TER determined the stillwater elevation to be 524.5 ft (160.0 m). However the Dresden, Unit 2 and 3 Updated Final Safety Analysis Report (UFSAR) Section 2.4.3 (Exelon, 2011) states "the stillwater elevation was at the site of about 525 ft (160 m)" resulting from the PMF with a peak discharge of 490,000 ft^3/s (13,880 m^3/s). The licensee stated that the UFSAR references the FRC TER, and reports the stillwater elevation of 524.5 ft (160.0 m), therefore elevation 524.5 ft (160.0 m) is the more precise maximum stillwater elevation. NRC staff agreed with using the more precise stillwater elevation, since the current design-basis is derived from the results of the report.

3.1.3 Flood-Related Changes to the Licensing Basis

The licensee reported no changes to the current licensing basis.

3.1.4 Changes to the Watershed and Local Area

The licensee's FHRR states that the most significant changes to the watershed include the expansion and development of the greater Chicago metropolitan area. Since the 1970s to the present, the developed land use has increased from approximately 16 to 26 percent. The FHRR also states that the watershed includes 57 dams that were constructed since the issuance of the Unit 3 license, and 30 dams constructed since the issuance of the Unit 2 license. There are 27 dams without documented completion dates. The licensee determined that no upstream dams have significant storage and all dams were included in the FHRR analysis of dam failures.

3.1.5 Current Licensing Basis Flood Protection and Pertinent Flood Mitigation Features

The licensee's FHRR states that the current licensing basis flood mitigation directs plant safe shutdown for both units when river elevations reach 509.0 ft (155.1 m). When river level rises to 517.0 ft (157.6 m), the doors to the reactor building will be opened and water will be allowed to flood the plant. The licensee stated that, per DNPS flooding procedure, a flood pump will provide reactor core cooling until such time that the water recedes from the site. The licensee stated that the flood pump will be elevated and operated above the design-basis flood elevation.

3.1.6 Additional Site Details to Assess the Flood Hazard

The licensee submitted to the docket other site details, as either part of the FHRR submittal or in response to requests for additional information. These included electronic topographic information as an enclosure to the FHRR (Exelon, 2013a) and electronic versions of hydrologic and hydraulic computer models (Barstow, 2014b).

3.1.7 Plant Walkdown Activities

The 50.54(f) letter was sent to licensees on March 12, 2012. Enclosure 4 of the 50.54(f) letter requested that licensees plan and perform plant walkdown activities to verify that current flood protection systems are available, functional, and implementable. Other parts of the 50.54(f) letter (Requested Information Item 1.c, and Step 6 of Attachment 1 to NTTF Recommendation 2.1, Flooding (Enclosure 2)) asked the licensee to report any relevant information from the results of the plant walkdown activities.

The licensee responded, by letter dated June 11, 2012, that they would perform the plant walkdown activities (Jury, 2012a). By letter dated November 26, 2012, the licensee provided the flood walkdown report for DNPS (Kaegi, 2012). The walkdown report was supplemented by letter, including RAI responses, dated January 31, 2014 (Barstow, 2014a).

The staff prepared a Staff Assessment report, dated July 17, 2014 (NRC, 2014b), to document its review of the walkdown report. The staff concluded that the licensee verified plant configuration with the current flood licensing basis. The staff assessment listed several licensee deficiencies including actions being taken or planned to address the deficiencies (NRC, 2014b). The staff noted no immediate safety concerns or any discrepancies between the walkdown report and the FHRR.

3.2 LIP and Associated Site Drainage

The licensee reported in Enclosure 1 of its FHRR (Exelon, 2013b) that the reevaluated flood hazard, including associated effects, for LIP and associated site drainage is based on a stillwater-surface elevation that varies at the seismic Category 1 structure's non-watertight doors from 517.6 to 518.1 ft (157.8 to 157.9 m).

This flood-causing mechanism is discussed in the licensee's current design basis. The current design basis probable maximum flood elevation for LIP and associated site drainage is based on a stillwater-surface elevation of 517.5 ft (157.7 m).

3.2.1 Model Inputs and Assumptions

The licensee's submitted a LIP analysis as an enclosure (Exelon, 2013b) to the FHRR. The licensee's analysis uses a two-dimensional (2D) hydrodynamic model, FLO-2D, Build 2009.006 (FLO-2D, 2009), with the following parameters:

- the 1-hour probable maximum precipitation event;
- Site topography including grading, drainage divides, buildings, and other site drainage features;
- Manning's Roughness Coefficients (Manning's n-values) to characterize the land cover of the site.

The licensee submitted the FLO-2D model inputs and outputs as an enclosure to the RAI response (Barstow, 2014b). The licensee's FLO-2D model boundaries are set along the cooling canal to the north and west of the site and at the slope breaks with drainage away from the site to the south and east. The FLO-2D model uses a grid input to represent the site topography. The licensee performed a sensitivity analysis of the grid size which optimized the grid spacing to reduce computing time without sacrificing precision. The licensee selected a grid size of 10-ft (3-m) by 10-ft (3-m) spacing.

The licensee assumed all site drainage system components are non-functional (active components) or completely blocked (passive components), per LIP Case 3 (most conservative) from NUREG/CR-7046 (NRC, 2011d). The licensee performed the evaluation independent of external high water events, meaning the LIP was assumed to be non-coincident to a river flood. The licensee considered the soil to be saturated and assigned negligible infiltration rates in the FLO-2D model. In RAI 2, the staff requested that the licensee discuss the potential effects of debris and offsite drainage on the boundary conditions (NRC, 2014a). In response to the RAI, the licensee analyzed the boundary conditions including the cooling water channels and south and east drainage divides (Barstow, 2014b). The licensee verified that the boundary conditions would be unaffected even if all the rainfall from offsite drainage was runoff and the channels were full of debris; therefore the LIP flooding elevations would be the same (Barstow, 2014b). The staff reviewed the licensee's verification and concurs with this conclusion.

3.2.2 Probable Maximum Precipitation

The licensee's analysis developed the 1-hour, 1-square mile probable maximum precipitation (PMP) event distribution using Hydrometerological Reports (HMRs) 51 and 52 (NOAA, 1978 and 1982). The licensee stated that the LIP event is defined by NUREG/CR-7046 (NRC, 2011d) as the 1-hour, 1-square mile PMP event. The licensee extrapolated from the PMP depth contour map provided in HMR 52. The licensee developed the distribution of the 1-hour PMP from the 5-, 15-, 30- and 60-minute time intervals from HMR 52. The licensee computed a cumulative depth of the 1-hour, 1-square mile PMP of 17.97 inches (45.28 cm). The staff verified the HMR 51 and HMR 52 computations based on the location of the DNPS, and concluded the PMP depths are appropriate.

Based on the staff's reviews of FHRRs to date, the staff observed that, when using transient rainfall runoff models, PMP events having longer than 1-hour durations may result in higher LIP flood elevations and longer periods of inundation than the 1-hour event. Staff also noted that LIP events deriving from PMPs having relatively short durations may result in limiting warning time and may likewise result in consequential LIP flood elevation (e.g., flood elevations above the openings to plant structures). The licensee is requested to evaluate the plant response time considering a range of precipitation durations associated with the LIP flood hazard (e.g., 1-, 6-, 12-, 24-, 48-, 72-hour PMPs). This evaluation should identify potentially limiting scenarios with respect to plant response when considering flood height, relevant associated effects, and flood-event duration parameters. This is Integrated Assessment Open Item No. 1.

3.2.3 Site Topography

The site topography was developed from a digital elevation model (DEM) from available Light Detection and Ranging (LiDAR) data and supplemental field surveys. The LiDAR data was validated using the licensee's 10 CFR 50 Appendix B Quality Assurance Program, and was used as the topographic baseline. The field survey was used to supplement the LiDAR data which allowed for incorporation of site features that were not identified in the LiDAR data. These features included low points, isolated concrete barriers and pads, and elevations adjacent to buildings.

3.2.4 Site Land Cover

The licensee characterized the land cover of the site using Manning's n values that are based on the ranges described in the FLO-2D Reference Manual (FLO-2D, 2009). The licensee determined the percentage of the entire site that each corresponding land cover surface occupied based on orthoimagery. The licensee performed a sensitivity analysis on the Manning's n-values which produced negligible differences in water surface elevations between the maximum and minimum n-values.

Staff concluded that the Manning's n-values selected by the licensee are appropriate based on the land cover surfaces at the DNPS.

3.2.5 FLO-2D Results

The licensee computed the water surface elevations, maximum flooding depths, maximum velocity, maximum resultant impact loading (forces due to moving water), and maximum resultant static load (height of water) using the FLO-2D model. The maximum flood elevation of 518.1 ft (157.9 m) occurs at several Category 1 structures. The flooding depths range between 0.1 ft (0.03 m) (Reactor Building, Unit 3) to 1.7 ft (0.5 m) (Turbine Building, Unit 2), which produce a maximum static load of 85.0 lbs. per ft (126.5 kg-force per m). The velocities are generally less than 1 foot per second (ft/s; 0.3 meters per second (m/s)), with resultant impact loads of 5 lbs. per ft (7.5 kg-force per m) or less.

The licensee noted that based on the sensitivity analysis of the grid size and Manning's n values (n-values), an accuracy of +/- 0.1 ft (0.03 m) should be taken when considering the flood elevations.

The staff reviewed the FLO-2D model input and output files provided by the licensee. In the course of the review, staff performed a mass balance verification and concluded that the runoff amount passing through the model boundary is less than the amount of rainfall. The difference in mass could result in a potential underestimation of the maximum water levels around the site. The licensee is requested to resolve the staff-identified numerical modeling issue associated with the LIP flood analyses, specifically the reduction of volume of outflow runoff as compared to the inflow precipitation, accounting for infiltration. This issue may relate to runoff from rooftops being removed from the numerical model domain rather than discharging to the ground surface near the structure or an adjacent area. This is Integrated Assessment Open Item No. 2.

3.2.6 Site-Specific Probable Maximum Precipitation

The licensee submitted Revision 4 of the LIP analysis report (Exelon, 2014) as part of the RAI response (Barstow, 2014b). The revised analysis uses the same topography, grid size, and land cover inputs, but replaces the HMR 51 and HMR 52 PMP analysis used in Revision 3 of the LIP analysis report (Exelon, 2013b) with a site-specific PMP analysis.

The staff performed a comparison of the two analyses to determine the significance of the site-specific PMP analysis, and whether a more detailed review of the analysis would be required. The staff compared the maximum 1-hour, 1-square mile precipitation between the two analyses, and the resultant maximum water surface elevation. Table 3.2.6-1 presents this comparison, including the percentage change from the HMR-based precipitation to the site-specific precipitation. The staff also compared the flood depths at the critical doors and bays, presented in Table 3.2.6-2, with a reference Figure 3.2.6-1, which is derived from licensee's Figure 4 from the LIP analysis report (Exelon, 2013b).

The staff noted that the site-specific PMP reduced the depth at critical doors and bays by a maximum of 0.2 ft (0.06 m) at Bay 124. The staff considered the difference in effective in flood depths between the site-specific PMP and the HMR-based PMP water depths to be small. For comparison, the typical height of a sandbag is 0.3 ft (0.1 m) (see *Sandbagging Techniques* (USACE-NWD, 2004)). Therefore, the staff did not review site-specific PMP methodology associated with the RAI response since the revised rainfall (model input) effectively produces the same water depths (model output) at the site.

3.2.7 NRC Staff Conclusion

The staff confirmed the licensee's conclusion that the reevaluated flood hazard for LIP and associated site drainage is not bounded by the current design-basis flood hazard; therefore, the licensee should include LIP and associated site drainage within the scope of the Integrated Assessment, as well as address Integrated Assessment Open Items 1 and 2. The information on flooding from LIP and associated site drainage that is specific to the data needs of the Integrated Assessment is described in Section 4 of this Staff Assessment.

3.3 Streams and Rivers

The licensee reported in the FHRR that the reevaluated flood hazard, including associated effects, for rivers is based on a stillwater-surface elevation of 524.9 ft (160.0 m) (Barstow, 2014b). The licensee used the same hydrologic and hydraulic analyses for the flooding from upstream dam failure mechanism discussed in Section 3.4 of this assessment, with the additional flooding volume provided by the failure of the upstream dams. The licensee compared the upstream peak flood elevations resulting from the flooding from rivers analysis and the flooding from upstream dam failure analysis, and determined that the riverine flood is bounded by the upstream dam failure flood. The licensee concluded that a more detailed analysis, including an analysis of associated effects (i.e. wind set-up and wave runup) and use of a two-dimensional model, at the DNPS site for flooding of rivers, was not required based on the Hierarchal Hazard Approach, since the dam failure mechanism is the bounding flood. The staff agreed with the licensee's decision, as any additional detailed analysis of a lower flood elevation using the same methodologies for associated effects and use of two-dimensional modeling would not result in a change in the hierarchy of the two flooding mechanisms (i.e., the river flooding hazard evaluation results (Section 3.3) would bound the dam failure flooding hazard evaluation results (Section 3.4) at the site). The licensee's current licensing basis discusses flooding of rivers. The current design-basis PMF elevation for rivers is a stillwater-surface elevation of 525.0 ft (160.0 m) and elevation 528.0 ft (160.9 m) when associated effects (wind waves) are included.

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; probable maximum snowpack; and a 100-year, cool-season precipitation would result in the maximum PMF flood elevation at the DNPS site. The licensee provided discussions of all of the alternatives, which included analyses of PMP using the guidance in HMR 51 and HMR 52 (NOAA, 1978; NOAA, 1982) and HMR 52 software (NOAA, 1982). The staff reviewed the alternatives; including reviewing the inputs and verifying that the guidance was used appropriately and properly. The staff verified that the results from all of the alternatives were reasonable, and that the alternative selected for further analysis produced the highest PMF flows at the DNPS site.

3.3.2 Probable Maximum Snowpack and Snowmelt Analysis

The licensee calculated the snowmelt values from the probable maximum snowpack using the *Runoff from Snowmelt* guidance provided by the USACE (USACE, 1998). The licensee assumed a fully ripe snowpack prior to the precipitation. The licensee analyzed two snow melting scenarios considered were rain-on-snow and rain-free. The licensee estimated the snow season PMP by interpolating the 10-square-mile seasonal PMP from HMR 53 (NOAA, 1980) to the DNPS site for each month of the snow season. Based on the results of the snow depths, the licensee identified critical months for the PMF analysis.
The staff reviewed the snow melt analysis, noted that the methodology selected was appropriate, and that the procedures were used appropriately. The 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 constructed a hydrologic model with USACE HEC-HMS software (Version 3.5) (USACE, 2010b). The model covers the combined Des Plaines and Kankakee Rivers watersheds upstream of the DNPS site, covering approximately 7,250 square miles (18,780 square kilometers). The licensee calibrated the HEC-HMS hydrologic model with the March 2009 historical peak flow, and validated the model using two storm events in May 2002 and July 1996. The licensee assumed that the navigational locks and dams acted as an open river without storage for the calibration/validation period. The staff verified the model was calibrated by comparing the output files results to the events. The staff reviewed the input parameters in the model, and verified that the parameters were conservative based on current engineering practice. The parameters reviewed in this manner were loss rate (set to a minimum for the software), and variable base flow (used the mean monthly flow per NUREG/CR-7046 guidance).

The licensee noted that the PMF flow calculated by the hydraulic model in the FHRR is almost 25 percent less than the PMF estimated by the hydraulic model in the current design-basis. The licensee did not include the current design-basis inflow in the FHRR. In RAI 4, the staff requested a comparison of the current design-basis and reevaluated hazard hydrologic models (NRC, 2014a). In its response to RAI 4 (Barstow, 2014b), the licensee stated that the difference in peak flows between the current design-basis and the reevaluated PMF are due to (1) the current design-basis detailed modeling inputs and outputs are not available; (2) the current design-basis peak flow for the Kankakee River is not aligned in time with the peak from the Des Plaines River; (3) routing through the steady-state modeling of the current design-basis covers a limited length of reach (1.4 mile (2.3 km)), compared to the unsteady-state modeling developed for the FHRR over 47 miles (76 km); and (4) the models applied for the FHRR were calibrated to a more refined scale than the current design-basis. Based on current engineering knowledge regarding increased precision of modern modeling techniques and the increased level of detail used in the reevaluated PMF analysis, the staff concluded the response to be reasonable.

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 performed an analysis for dynamic channel routing of the inflow with a hydraulic model in the HEC-RAS software (version 4.1) (USACE, 2010a). The licensee obtained a maximum stillwater elevation of 524.9 ft (160.0 m) at the most upstream point of the DNPS site.

The licensee developed the HEC-RAS model for a reach of the Des Plaines and Illinois Rivers of sufficient length to encompass the entire site, and included a short reach for the Kankakee River at the confluence with the Des Plaines River. The licensee developed cross sections and floodplain geometries for the Des Plaines, Illinois, and Kankakee Rivers. A total of 11 bridges were modeled with geometries determined from aerial photographs. The licensee used the HEC-HMS results for the boundary conditions for the HEC-RAS model. The staff verified the HEC-RAS model setup, including geometries and flow inputs. Staff verification involved a review of geometry files including a review of the cross sections, structures, and the stream delineation. The staff executed the model to ensure no modeling errors appeared.
The licensee calibrated the HEC-RAS model with the historical event in September of 2008, using four corresponding USGS gauges that fall within the model boundaries. The licensee assumed normal operation of the dams as defined by the USACE Hydraulic Design of Navigation Dams (USACE, 1987), and considered dam inflow and dam outflow were equivalent. The FHRR states that the calibration focused on achieving the historical peak flood elevation at the dam pools by adjusting the Manning's n-value in the channel, weir coefficients, and gate operations.

The staff noted that due to the lack of reservoir inflow and the uncertainty about gate operation at the downstream Dresden Lock and Dam, multiple sets of parameter values could possibly achieve the same flood elevation at a dam pool for this calibration. In RAI 5, the staff requested that the licensee describe the effect of pool inflow and gate operation uncertainty on the

HEC-RAS model results (NRC, 2014a). In its response to RAI 5, dated May 19, 2014 (Barstow, 2014b), the licensee performed a sensitivity analysis for pool inflows and gate operations at the Dresden Lock and Dam. The results of the licensee's sensitivity analysis indicate that the flood elevation at the site is not sensitive to gate operations at the dam. The increase in flood elevation is equal to or less than 0.03 ft (0.01 m). The staff reviewed the data provided and agreed that the total flow at the DNPS site is not sensitive to the Dresden Lock and Dam reservoir operation and inflow.

The licensee selected Manning's n-values for the stream channel within the range specified in the HEC-RAS Hydraulic Reference Manual (USACE, 2010c) and based on land cover imagery. The staff performed an independent sensitivity analysis of Manning's n-value to the flood elevation. The staff concluded that any sensitivity was not significant due to the fact that the licensee used the HEC-RAS model as the input into a more detailed two-dimensional modeling in the flooding from upstream dam failures (see Section 3.4).

3.3.5 NRC Staff Conclusion

The staff reviewed the analyses, performed sensitivity analyses, and performed simplified independent verifications. The staff reviewed the various hydrologic and hydraulic models including review of the inputs, parameters, selection of parameters, and methodologies, which staff compared to present-day methodologies and regulatory guidance. The licensee used the flooding from rivers as the base hydrologic input into the flooding from upstream dam failure mechanism, with only the inclusion of the additional water volume from the failure of the upstream dams. Since the two evaluations (river flooding (Section 3.3) and dam failure (Section 3.4)) are effectively the same except for the additional flood volume from the dam failure, the staff agreed with the licensee's conclusion that rivers flood hazard evaluation did not require evaluation of the associated effects (see Section 2.2.2) as part of the river flooding hazard analysis. The associated effected were evaluated as part of the dam failure hazard analysis (Section 3.4).

3.4 Failure of Dams and Onsite Water Control/Storage Structures

The licensee reported in the FHRR that the reevaluated flood hazard, including associated effects, for failure of upstream dams is based on a maximum stillwater-surface elevation of 524.8 ft (160.0 m), which results from the cascading hydrologic failure of five critical upstream dams due to the PMF event analyzed in Section 3.3, and including wind waves and runup results in a maximum elevation of 529.0 ft (161.2 m). The licensee determined that the bounding failure mechanism is hydrologic dam failure, and the licensee assumed that all critical upstream dams failed during the PMF event. The licensee computed a peakflood elevation of 525.8 ft (160.3 m) for this hazard mechanism using a one-dimensional model; the licensee subsequently used the results of this model as input into a two-dimensional hydrodynamic model near the DNPS site. The staff noted that the peak flood elevation from flooding due to rivers hazard evaluation, 524.8 ft (160.0 m), is bounded by the maximum flood elevation computation, 525.8 ft (160.3 m), from flooding from upstream dam failure hazard evaluation. This flood-causing mechanism is discussed in the licensee's current design basis, but only for the failure of the onsite Dresden Cooling Lake, with no analysis of the failure of upstream dams.

The current design basis probable maximum flood elevation for failure of the Dresden Cooling Lake is based on a stillwater-surface elevation of 508.2 ft (154.9 m).

3.4.1 Critical Dam Evaluation and Selection

The licensee evaluated 137 dams in the watershed, identified by using the National Atlas and the USACE National Inventory of Dams. The licensee assessed the reservoirs by using the peak outflow with attenuation method from JLD-ISG-2013-01 (NRC, 2013b) to screen non-critical and potentially critical dams. The licensee identified five critical dams: Busse Woods Dam, Lockport Lock and Dam, Brandon Road Lock and Dam, Sauk Trail Dam, and Fawell Dam. The non-critical dams were lumped together, and their failures were analyzed using the hydrologic model shown in JLD-ISG-2013-01 (NRC, 2013b). The outflow hydrograph from the lumped dams were incorporated into the HEC-HMS model as a single discharge at the respective cluster sub-basin outlet. The staff reviewed the selection process, and concluded that the dams selected would be considered critical based upon the ISG methodology. The staff performed this review using the licensee's dam summaries. The staff concluded that the clustering of non-critical dams would result in a more conservative (i.e. higher) flow and conformed to the ISG.

The licensee also analyzed the Dresden Cooling Lake Dam as a failure of a potentially critical onsite water storage structure, but determined that the failure does not increase the flooding maximum flood elevation at the DNPS site due to the existing tailwater effect within the Kankakee River. The staff reviewed the analysis of the licensee's exclusion of the Dresden Cooling Lake Dam, and concluded the exclusion to be reasonable, based upon the negligible (<0.05 ft (0.01 m)) increase in the maximum flood elevation.

3.4.2 Upstream Dam Failure Mechanism Summary

The licensee evaluated dam failures for three failure mechanisms (hydrologic, seismically induced, and sunny day dam failures). To identify the worst flooding at the site, the licensee assumed that flows resulting from individual and domino-like dam failures arrive at the site coincidentally and also at the time when the peak flow from the Kankakee River arrives. The licensee used the same controlling PMF snowmelt sequence described in Section 3.3 as the base flow for the hydrologic dam failure analysis. The licensee stated that the sunny day failure mechanism would be bounded by the hydrologic and seismic induced dam failure mechanisms because of the lower coincident hydrologic conditions. The licensee, therefore, did not analyze the sunny day failure mechanism. The staff determined that this approach to dam failure mechanism selection is consistent with present-day guidance and methodology for dam failure analysis, such as NUREG/CR-7046 (NRC, 2012). The staff considered the sunny day failure mechanism would be bounded, as the licensee stated, based upon the much greater PMF flow coincident with the hydrologic dam failure.

3.4.3 Hydrologic Dam Failure Analysis

To analyze the flooding from a hydrologic failure of upstream dams, the licensee modeled the combined snowmelt and rainfall PMF (see Section 3.3 for more details of this hydrologic model) and dam failure flow hydrographs in HEC-HMS to produce an upstream dam failure flow model.

For each dam, the licensee evaluated the most appropriate breach – overtopping or breach of the principal and emergency spillways – for each dam based upon dam type. The licensee maximized breach parameters were based on USACE guidance (USACE, 1980). The staff reviewed the breach selection for each critical dam, and compared them to USACE guidance values (USACE, 1980). Staff determined that the breach parameters are reasonably conservative and conform to standard engineering practices. The licensee used HEC-RAS to compute hydrographs at various cross sections along the simulated river channel system. The licensee obtained a maximum flood elevation of 525.8 ft (160.3 m) at the DNPS site under the controlling PMF scenario with cascading dam failure of all critical upstream dams.
The licensee used the two-dimensional (2-D) hydraulic model RiverFLO-2D (RiverFLO-2D, 2012) to generate water surface elevations for the river reach from just upstream and just downstream of the DNPS site, using the boundary conditions developed from the HEC-RAS model. The staff reviewed the RiverFLO-2D model parameters, specifically the grid (i.e. sizing and boundary), modeling of structures, and roughness coefficients.

As the final step, the licensee computed more detailed stillwater elevations and the effects of wave activity by using the FLO-2D hydrodynamic model with hydrograph input from RiverFLO-2D model at the DNPS site boundaries. The licensee reported a range of stillwater and wave runup elevations at various safety related, Seismic Category 1 structures, with a maximum stillwater elevation of 524.8 ft (160.0 m), and a maximum wave runup elevation of 529.0 ft (161.2 m). The resulting maximum wave velocity ranges from 2.9 to 6.9 ft/s (0.9 to 2.1 m/s), and hydrodynamic pressure varies from 20.9 to 117.2 psf (101.9 to 571.9 kilogram-force/m^2) at various seismic Category 1 structures (Exelon, 2013b). The staff reviewed the model including parameters such as grid size, Manning's n-values, and boundary conditions. The staff also performed sensitivity analyses for the Manning's n-values. In the first sensitivity analysis, staff increased the Manning's n-values by 10 percent within all the grids in the model. The results indicate that the sensitivity of water surface elevation to n value for the FLO-2D model is minimal (<0.1 ft (<0.03 m)). The staff concluded the model parameters section, and hence the results, were reasonable and appropriate for the modeled conditions.

3.4.4 Seismic Upstream Dam Failure

The licensee analyzed the seismic dam failure using the same HEC-HMS and HEC-RAS models previously discussed (Sections 3.3 and this section). To determine the seismic dam failure process, the licensee used the combined events defined in NUREG/CR-7046 (NRC, 2012). The licensee determined that a combination of (1) the lesser of the 50 percent PMF and the 500 year flood; (2) a flood caused by the dam failure resulting from an operating basis earthquake (OBE), coincident with the peak of the flood in item (1); and (3) waves induced by 2 year wind speed applied along the critical direction results in the largest seismically induced flood. The licensee reduced the dam failure time to 0.5 hours to more closely model a typical seismic failure, and the licensee assumed the Lockport Lock and Dam and Brandon Road Lock and Dam concrete structures failed. The licensee computed a peak flood elevation due to seismic dam failure of 515.5 ft (157.1 m), which does not exceed site grade. The staff reviewed the seismic failure of the dams by reviewing the parameters selected including dam failure timing and breach selection, and concluded the analysis to be reasonable. Since the peak flood elevation produced from flooding by seismic dam failure scenario is much lower than the maximum flood elevation produced from flooding by hydrologic dam failure, staff concluded a more detailed review of the licensee's analysis was not warranted.

3.4.5 Upstream Dam Failure Timing and Duration

In RAI 6, the staff requested that the licensee evaluate scenarios that showed the shortest arrival time in the analysis for the stream flooding mechanism and summarize the final results for response times under the various scenarios in the FHRR (NRC, 2014a). The licensee's response to RAI 6, dated May 19, 2014 (Barstow, 2014b), described additional analyses, as requested by the staff, and included the timing from seismic dam failure as well. The licensee calculated the time for the water surface elevation to reach the critical elevations and the maximum flood elevation, and the duration of time while the water surface elevation exceeds the intake structure elevation and site grade for two scenarios. The licensee provided a comparison table that includes all results for these two scenarios (Barstow, 2014b). The licensee's results for time to reach critical elevations and duration exceeding critical elevations are summarized in Table 3.4-1. The staff reviewed the timing analyses by reviewing the hydrographs from each alternative analysis (e.g. hydrologic dam failure, seismic dam failure, etc.), and comparing the times to the various critical heights. The staff concluded that the evaluation of timing duration results was reasonable.

3.4.6 Other Associated Effects of Upstream Dam Failure

The staff noted that the PMF coincident with dam failure may result in transport of sediments and debris carried by floodwater. The licensee did not consider, in the FHRR, the effect of transport of sediment near the DNPS site. In RAI 8 (NRC, 2014a), the staff requested an evaluation of transport of sediment near the site, per JLD-ISG-2013-01 (NRC, 2013b). In its response to RAI 8, dated May 19, 2014 (Barstow, 2014b), the licensee performed an analysis to evaluate sediment transport near the site. The licensee used methods and equations to estimate for natural sediments the shear velocity, sediment setting velocity, and its ratio. The results indicate that the primary mode of sediment transport is in suspension at most of representative locations throughout the powerblock area and therefore, sedimentation at the site during the controlling PMF is limited. The staff reviewed the analysis, and verified the results by performing a single computation used in the analysis. The staff verified that the equations and reference tables were from accepted sources, and concluded they produced reasonable results.

3.4.7 NRC Staff Conclusion

NRC staff reviewed the assumptions and approach used in the flooding from upstream dams analysis, and concluded the approach appropriate and assumptions to be reasonable. The staff verified that the models were consistent with results presented in the FHRR and that in cases where the one model output was used as an input to another model, the two data sets were exactly the same. The staff verified the references used, to ensure that they met standard engineering practices and NRC guidance. The staff confirmed the licensee's conclusion that the reevaluated flood hazard for failure of dams and onsite water control or storage structures is not bounded by the current design basis flood hazard; therefore, the licensee must include failure of dams and onsite water control or storage structures within the scope of the Integrated Assessment. Section 4 of this staff assessment describes the information on flooding from failure of dams and onsite water control or storage structures that should be included in the Integrated Assessment.

3.5 Storm Surge

The licensee reported in the FHRR that the reevaluated hazard, including associated effects, for storm surge does not inundate the plant site. This flood-causing mechanism is discussed in the licensee's current design basis, but was considered not plausible since DNPS is an inland location and does not connect directly with any bodies of water capable of producing storm surge.

The staff confirmed the licensee's conclusion that the reevaluated hazard for flooding from storm surge is bounded by the current design basis flood hazard.

3.6 Seiche

The licensee reported in the FHRR that the reevaluated hazard, including associated effects, for seiche does not inundate the plant site. This flood-causing mechanism is discussed in the licensee's current design-basis, but was considered not plausible since DNPS is an inland location and does not connect directly with any bodies of water capable of producing seiche. The staff confirmed the licensee's conclusion that the reevaluated hazard for flooding from seiche is bounded by the current design-basis flood hazard.

3.7 Tsunami

The licensee reported in the FHRR that the reevaluated hazard, including associated effects, for tsunami does not inundate the plant site. This flood-causing mechanism is discussed in the licensee's current design-basis, but was considered not plausible due to the inland location of DNPS which does not connect directly with any bodies of water capable of producing a tsunami. The staff confirmed the licensee's conclusion that the reevaluated hazard for flooding from tsunami is bounded by the current design-basis flood hazard.

3.8 Ice-Induced Flooding

The licensee reported in the FHRR that the reevaluated flood hazard, including associated effects, for ice-induced flooding is based on a stillwater-surface elevation of 515.5 ft (157.1 m) for an upstream ice dam collapse and 514.6 ft (156.8 m) for downstream ice jam. This flood-causing mechanism is not discussed in the licensee's current design basis.

The licensee used the USACE National Ice Jam Database (USACE, 2012) to determine the most severe historical ice flooding events. The peak elevation of the historic ice jam flooding was assumed to represent the full height of the ice jam relative to the normal water surface elevation at the recorded location. The maximum downstream ice jam was determined to be 31.9 ft (9.7 m) above normal river level, based on a historic maximum occurring on the Fox River, a tributary of the Illinois River. The maximum downstream ice jam was transposed to the nearest downstream river crossing at Dresden Island Lock and Dam on the lower elevation pool of the Marseilles Lock and Dam. Assuming the maximum ice jam occurs at the nearest downstream river crossing results in a water surface elevation of 514.6 ft (156.8 m). The staff reviewed the analysis, including verifying information from the USACE National Ice Jam Database (USACE, 2013) and determined that the analysis was consistent with present-day methodologies.

For upstream ice jam failure analysis, the licensee used the National Weather Service (NWS) simplified dam failure equation (Fread et al., 1991) to determine the peak outflow. The ice jam is considered a concrete type dam for the purposed of the estimating the breach parameters. The breach width is considered to be multiple monoliths equivalent to the distance between river crossing piers. The most conservative breach development time is 0.1 hours. The peak outflow is transposed to the site without attenuation. A corresponding water surface elevation is then determined based on the most upstream HEC-RAS cross section rating curve from the hydraulic model previously discussed. The staff reviewed the analysis and concluded the analysis was consistent with present-day methodologies.

The staff confirmed the licensee's conclusion that the reevaluated hazard from flooding from ice-induced flooding is not bounded by the current design-basis flood hazard. However, the staff also confirmed the licensee's conclusion that the flood hazard from ice-induced flooding alone would not inundate the site. Therefore, ice-induced flooding does not need to be included within the scope of the Integrated Assessment.

3.9 Channel Migrations or Diversions

The licensee reported in the FHRR that the reevaluated hazard, including associated effects, for channel migrations or diversions is bounded by other flood causing mechanisms.
The FHRR states that local control structures and flows that might play a role in channel migration are outside the licensee's authority. In RAI 10 (NRC, 2014a), staff requested that the licensee describe the available historical topographic maps and other information on the channel material, consistent with NUREG/CR-7046 (NRC, 2011d) that would assist staff in determining if channel migrations or diversions could be a bounding flood hazard.

In response to RAI 10 (Barstow, 2014b), the licensee provided detailed historical topographic maps and discussions of the historical channel diversions of the Kankakee and Des Plaines Rivers at the confluence with the Illinois River. In addition, the licensee discussed the potential of local landslides which could influence channel migration. The licensee determined that available historical information suggested that no significant migrations or diversions have occurred, and therefore the changes to the channels would not significantly increase water surface elevations at the site. The staff reviewed the response and concluded that it was reasonable based on the historical data provided.

The staff confirmed the licensee's conclusion that the reevaluated hazard from flooding from channel migrations or diversions is not bounded by the current design-basis flood hazard. However, the staff also confirmed the licensee's conclusion that the flood hazard from channel migrations or diversions alone would not inundate the site. Therefore, channel migrations or diversions do not need to be included within the scope of the Integrated Assessment.

4.0 INTEGRATED ASSESSMENT AND ASSOCIATED HAZARD DATA

The staff confirmed that, for certain flooding mechanisms, the reevaluated hazard is not bounded by the current design-basis flood hazard. Therefore, the staff concludes that an Integrated Assessment is necessary, and that it must consider the following flood-causing mechanisms: (a) LIP and associated site drainage, and (b) and upstream dam failure and associated effects.

Section 5 of JLD-ISG-2012-05 (NRC, 2012c) describes the flood hazard parameters to complete the Integrated Assessment. The staff reviewed these parameters, and concluded that the following parameters from this Staff Assessment are appropriate as input to the Integrated Assessment:

- Flood event duration, including warning time and intermediate water surface elevations that trigger actions by plant personnel, as defined in JLD-ISG-2012-05. Flood event durations for the flood-causing mechanisms identified above are shown in Table 4.0-1.

- Flood height and associated effects, as defined in JLD-ISG-2012-05. Flood height and associated effects for the flood-causing mechanisms identified above are shown in Table 4.0-2.

The staff requests that the licensee address the following open items as discussed in previous sections during the integrated assessment:

1. The licensee is requested to evaluate the plant response time considering a range of precipitation durations associated with the LIP flood hazard (e.g., 1-, 6-, 12-, 24-, 48-, 72-hour PMPs). This evaluation should identify potentially limiting scenarios with respect to plant response when considering flood height, relevant associated effects, and flood-event duration parameters. This Integrated Assessment Open Item is discussed in more detail, including background, in Section 3.2.2 of this staff assessment.

2. The licensee is requested to resolve the staff-identified numerical modeling issue associated with the LIP flood analyses, specifically the reduction of volume of outflow runoff as compared to the inflow precipitation, accounting for infiltration. This issue may relate to runoff from rooftops being removed from the numerical model domain rather than discharging to the ground surface near the structure or an adjacent area. This Integrated Assessment Open Item is discussed in more detail, including background, in Section 3.2.5 of this staff assessment.

Based upon the preceding analysis, staff confirmed that the reevaluated flood hazard information defined in the sections above, with the exception of identified Integrated Assessment Open Items, is appropriate input to the Integrated Assessment.

5.0 CONCLUSION

The NRC staff has reviewed the information provided for the reevaluated flood-causing mechanisms of Dresden Nuclear Power Station, Units. 2 and 3. Based on its review, 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, staff confirmed the licensee's conclusions that (a) the reevaluated flood hazard results for LIP and failure of dams are not bounded by the current design-basis flood hazard, (b) an Integrated Assessment including LIP and failure of dams, including associated effects, is expected to be submitted by the licensee, and (c) the reevaluated flood-causing mechanism information is appropriate input to the Integrated Assessment as described in JLD-ISG-2012-05 (NRC, 2012c).

The NRC staff identified two Integrated Assessment Open Items related to the LIP FLO-2D model, LIP durations, and LIP flood parameters comparison between the site specific PMP and HMR-based models. The Integrated Assessment Open Items are summarized in Table 5.0-1. Therefore, the NRC is not providing finality on the flood parameters related to LIP as part of this Staff Assessment.

6.0 REFERENCES

Notes: (1) ADAMS Accession Nos. refer to documents available through NRC's Agencywide Document Access and Management System (ADAMS). Publicly-available ADAMS documents may be accessed through http://www.nrc.gov/reading-rm/adams.html. (2) "n.d." indicates no date is available or relevant, for example for sources that are updated by parts. "n.d.-a", "n.d.-b" indicate multiple undated references from the same source.

6.1 U.S. Nuclear Regulatory Commission (NRC) Documents and Publications:

- NRC, 2007, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition", NUREG-0800, ADAMS stores the Standard Review Plan as multiple ADAMS documents, which are accessed through the web page http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr0800/.

- NRC, 2011a, "Recommendations for Enhancing Reactor Safety in the 21st Century: The Near-Term Task Force Review of Insights from the Fukushima Dai-Ichi Accident," Enclosure to Commission Paper SECY-11-0093, July 12, 2011, ADAMS Accession No. ML11186A950.

- NRC, 2011b, "Recommended Actions to be Taken Without Delay from the Near-Term Task Force Report," Commission Paper SECY-11-0124, September 9, 2011, ADAMS Accession No. ML11245A158.

- NRC, 2011c, "Prioritization of Recommended Actions to be Taken in Response to Fukushima Lessons Learned," Commission Paper SECY-11-0137, October 3, 2011, ADAMS Accession No. ML11272A111.

- NRC, 2011d, "Design-Basis Flood Estimation for Site Characterization at Nuclear Power Plants in the United State of America," NUREG/CR-7046, November 2011, ADAMS Accession No. ML11321A195.

- NRC, 2012a, letter from Eric J. Leeds, Director, Office of Nuclear Reactor Regulation and Michael R. Johnson, Director, Office of New Reactors, to All Power Reactor Licensees and Holders of Construction Permits in Active or Deferred Status, March 12, 2012, ADAMS Accession No. ML12053A340.

- NRC, 2012b, letter from Eric J. Leeds, Director, Office of Nuclear Reactor Regulation, to All Power Reactor Licensees and Holders of Construction Permits in Active or Deferred Status, May 11, 2012, ADAMS Accession No. ML12097A509.

- NRC, 2012c, "Guidance for Performing the Integrated Assessment for External Flooding," Japan Lessons-Learned Project Directorate, Interim Staff Guidance JLD-ISG-2012-05, Revision 0, November 30, 2012, ADAMS Accession No. ML12311A214.

- NRC, 2013a, “Guidance for Performing a Tsunami, Surge, or Seiche Hazard Assessment,” Japan Lessons-Learned Project Directorate, Interim Staff Guidance JLD-ISG-2012-06, Revision 0, January 4, 2013, ADAMS Accession No. ML12314A412.

- NRC, 2013b, “Guidance For Assessment of Flooding Hazards Due to Dam Failure,” Japan Lessons-Learned Project Directorate, Interim Staff Guidance JLD-ISG-2013-01, Revision 0, July 29, 2013, ADAMS Accession No. ML13151A153.

- NRC, 2014a, “Dresden Nuclear Power Station, Units 2 and 3 – Request for Additional Information Regarding Fukushima Lessons Learned – Flood Hazard Reevaluation Report (TAC Nos. MF1795 and MF1796),” Division of Operating Reactor Licensing, April 9, 2014, ADAMS Accession No. ML14070A589.

- NRC, 2014b, “Dresden Nuclear Power Station, Units 2 and 3 – Staff Assessment of the Flooding Walkdown Report Supporting Implementation of the Near-Term Task Force Recommendation 2.3 Related to the Fukushima Dai-Ichi Nuclear Power Plant Accident (TAC Nos. MF0223 and MF0224),” Division of Operating Reactor Licensing, ADAMS Accession No. ML14184B288.

6.2 Codes and Standards

- ANSI/ANS (American National Standards Institute/American Nuclear Society), 1992, ANSI/ANS-2.8-1992, “Determining Design Basis Flooding at Power Reactor Sites,” American Nuclear Society, LaGrange Park, IL, July 1992.

6.3 Other References:

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

Flood-Causing Mechanism	SRP Section(s) and JLD-ISG
LIP and Associated Drainage	SRP 2.4.2 SRP 2.4.3
Streams and Rivers	SRP 2.4.2 SRP 2.4.3
Failure of Dams and Onsite Water Control/Storage Structures	SRP 2.4.4 JLD-ISG-2013-01
Storm Surge	SRP 2.4.5 JLD-ISG-2012-06
Seiche	SRP 2.4.5 JLD-ISG-2012-06
Tsunami	SRP 2.4.6 JLD-ISG-2012-06
Ice-Induced	SRP 2.4.7
Channel Migrations or Diversions	SRP 2.4.9

Notes:

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

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

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

Table 3.0-1. Summary of Controlling Flood-Causing Mechanisms

Reevaluated Flood-Causing Mechanisms and Associated Effects that May Exceed the Powerblock Elevation 517.0 ft (157.6 m) NGVD29[1]	ELEVATION ft (m) NGVD29
LIP and Associated Drainage	518.1 (157.9)
Flooding in Streams and Rivers[2]	524.9 (160.0)
Failure of Dams and Onsite Water Control/Storage Structures	529.0 (161.2)

[1] Flood Height and Associated Effects as defined in JLD-ISG-2012-05 (NRC, 2012c).

[2] Flooding in Streams and Rivers is the base flow for the Failure of Dams and Onsite Water Control/Storage Structures.

Table 3.1.2-1. Current Design Basis Flood Hazards

Flooding Mechanism	Stillwater Elevation ft (m) NGVD29	Associated Effects	Current Design Basis Flood Elevation ft (m) NGVD29	Reference
LIP and Associated Drainage	517.5 (157.7)	Not discussed	517.5 (157.7)	Exelon, 2013b Section 5
Streams and Rivers	525.0 (160.0)	3.0 ft (0.9 m) (wind wave)	528.0 (160.9)	FHRR, Section 2.a
Failure of Dams and Onsite Water Control/Storage Structures	508.2 (154.9)	Not discussed	508.2 (154.9)	FHRR, Section 2.a
Storm Surge	Not applicable to DNPS site.			FHRR, Section 2.a
Seiche	Not applicable to DNPS site.			FHRR, Section 2.a
Tsunami	Not applicable to DNPS site.			FHRR, Section 2.a
Ice-Induced	No elevation provided in UFSAR.			FHRR, Section 2.a
Channel Migrations or Diversions	No elevation provided in UFSAR; discussed in reference to control of locks and dams by USACE.			FHRR, Section 2.a

Table 3.2.6-1. Comparison of HMR and Site Specific Probable Maximum Precipitation (PMP) LIP Analyses (Exelon, 2013b)[1]

Parameter	HMR LIP Analysis[1]	Site specific PMP LIP Analysis[2]	Differential	Percentage Differential
Precipitation, inches (cm)	18.0 (45.6)	13.9 (35.3)	4.1 (10.3)	22.6
Maximum Flood Elevation - Several Locations, ft (m) NAVD88	517.80 (157.83)[3]	517.61 (157.77)[3]	0.19 (0.06)[3]	0.0
Maximum Flooding Depth - Turbine Building, Unit 2, ft (m)	1.65 (0.50)[3]	1.58 (0.48)[3]	0.07 (0.02)[3]	4.2
Maximum Velocity - Turbine Building, Unit 3, ft/s (m/s)	1.54 (0.47)[3]	1.35 (0.41)[3]	0.19 (0.06)[3]	12.3
Maximum Static Load - Turbine Building, Unit 2, lbs/ft (kg-force/m)	85.0 (126.5)	78.3 (116.5)	6.7 (10.0)	7.9
Maximum Impact Load - Turbine Building Unit 3, lbs/ft (kg-force/m)	5.0 (7.5)	3.0 (4.4)	2.0 (3.1)	41.3

[1] Values obtained from Exelon, 2013b

[2] Values obtained from Exelon, 2014

[3] Significant figures extended by one decimal place for this comparison to precisely present data.

Table 3.2.6-2. Comparison of HMR and Site Specific Probable Maximum Precipitation Results at Critical Doors and Bays[1]

	HMR Analysis Results (Exelon, 2013b)		Site Specific PMP Analysis Results (Exelon, 2014)		
Door/Bay Number	**Maximum Flood Depth ft (m)[2]**	**Depth Above Lowest Non-Watertight Opening ft (m)[2]**	**Maximum Flood Depth ft (m)[2]**	**Depth Above Lowest Non-Watertight Opening ft (m)[2]**	**Difference in Depth ft (m)[2]**
Bay 124	0.93 (0.28)	0.58 (0.18)	0.74 (0.23)	0.39 (0.12)	0.19 (0.06)
Door 125	0.72 (0.22)	0.55 (0.17)	0.54 (0.16)	0.37 (0.11)	0.18 (0.05)
Door 126	0.87 (0.27)	0.55 (0.17)	0.68 (0.21)	0.36 (0.11)	0.19 (0.06)
Bay 127	0.98 (0.30)	0.54 (0.16)	0.8 (0.24)	0.36 (0.11)	0.18 (0.05)
Door 128	1.07 (0.33)	0.54 (0.16)	0.9 (0.27)	0.37 (0.11)	0.17 (0.05)
Bay 129	1.58 (0.48)	0.55 (0.17)	1.42 (0.43)	0.39 (0.12)	0.16 (0.05)
Door 130	1.19 (0.36)	0.54 (0.16)	1.05 (0.32)	0.4 (0.12)	0.14 (0.04)
Door 131	1.03 (0.31)	0.54 (0.16)	0.91 (0.28)	0.4 (0.12)	0.12 (0.04)
Bay 132	0.94 (0.29)	0.52 (0.16)	0.82 (0.25)	0.39 (0.12)	0.12 (0.04)
Door 133	0.83 (0.25)	0.49 (0.15)	0.72 (0.22)	0.38 (0.12)	0.11 (0.03)
Door 134	1.45 (0.44)	0.46 (0.14)	1.34 (0.41)	0.35 (0.11)	0.11 (0.03)
Door 135	0.88 (0.27)	0.36 (0.11)	0.79 (0.24)	0.27 (0.08)	0.09 (0.03)
Door 136	0.89 (0.27)	0.21 (0.06)	0.81 (0.25)	0.13 (0.04)	0.08 (0.02)
Door 137	0.70 (0.21)	0.12 (0.04)	0.61 (0.19)	0.03 (0.01)	0.09 (0.03)
Door 138	0.78 (0.24)	0.12 (0.04)	0.69 (0.21)	0.03 (0.01)	0.09 (0.03)
Door 139	0.86 (0.26)	0.09 (0.03)	0.78 (0.24)	0.01 (0.003)	0.08 (0.02)
Bay 140	0.66 (0.20)	0.28 (0.09)	0.6 (0.18)	0.22 (0.07)	0.06 (0.02)
Door 141	1.07 (0.33)	0.27 (0.08)	0.95 (0.29)	0.15 (0.05)	0.12 (0.04)

[1] See Figure 3.2.6-1 for aerial location of doors and bays.

[2] Significant figures extended by one decimal place for this comparison to precisely present data.

Table 3.4-1. Summary of Time to Reach the Critical WSE and Duration of Exceeding That Level (Barstow, 2014b)

Critical Water Surface Elevation (WSE) at the Site	Time to Reach the Critical WSE	Duration of Exceeding the Critical WSE
509.0 ft (155.1 m) (NGVD29)	10 hour 5 min[1]	14 days 0 hour 50 min[2]
517.0 ft (157.6 m) (NGVD29)	23 hour 25 min[1]	6 days 15 hour 0 min[3]
Maximum WSE	4 d 18 hour 10 min[3]	N/A

[1] The all season PMF scenario with coincident hydrologic dam failure.
[2] The PMF scenario and no dam failure.
[3] The cool season PMF scenario with coincident hydrologic dam failure

Table 4.0-1: Flood Event Duration for Flood-Causing Mechanisms to be Examined in the Integrated Assessment

Flood-Causing Mechanism	Time Available for Preparation for Flood Event	Duration of Inundation of Site	Time for Water to Recede from Site
LIP and Associated Drainage	See Integrated Assessment Open Items	See Integrated Assessment Open Items	See Integrated Assessment Opens Items
Failure of Dams and Onsite Water Control/Storage Structures	1 day, 12 hours, and 45 minutes (Kaegi, 2013)	6 days, 15 hours (Table 6.1, Barstow, 2014b)	11 days, 8 hours (Table 6.1, Barstow, 2014b)

Table 4.0-2: Reevaluated Flood Hazards for Flood-Causing Mechanisms to be Examined in the Integrated Assessment

Flood-Causing Mechanism	Stillwater Elevation, ft (m) NGVD29	Associated Effects	Reevaluated Flood Hazard, ft (m) NGVD29	Reference
LIP and Associated Drainage	Varies with maximum of 518.1 (157.9)	None	Varies with maximum of 518.1 (157.9)	Exelon, 2013b, Section 4
Failure of Dams and Onsite Water Control/Storage Structures	Varies with a maximum of 524.8 (160.0)	Varies with a maximum of 4.2 (1.3) (Wind wave and wave runup)	Varies with a maximum of 529.0 (161.2)	FHRR, Section 3, Table 1, and Section 4, Table 6

Table 4.0-3 Integrated Assessment Associated Effects Inputs

	Flooding Mechanism	
Associated Effects Factor	**Local Intense Precipitation**	**Failure of Dams and Onsite Water Control/Storage Structures**
Hydrodynamic loading at plant grade	Minimal, not bounding (FHRR, Sect. 4.2)	117.2 psf (572.2 kg-force/m^2) (FHRR, Table 4)
Debris loading at plant grade	None	Varies with maximum of 3,387 lbs (1,536 kg) at Unit 2 Turbine Building (Barstow, 2014b)
Sediment loading at plant grade	None	Minimal effect (Barstow, 2014b)
Sediment deposition and erosion	None	Minimal effect (Barstow, 2014b)
Concurrent conditions, including adverse weather	None	Hail, strong winds, and tornadoes (Barstow, 2014b)
Groundwater ingress	None	Bounded (Barstow, 2014b)
Other pertinent factors (e.g., waterborne projectiles)	None	Examined barge collision (Barstow, 2014b)

Table 5.0-1: Integrated Assessment Open Items

Integrated Assessment Open Items: The Integrated Assessment Open Items set forth in the Staff Assessment and summarized in the table below identify certain matters that will be addressed in the Integrated Assessment submitted by the licensee. These items constitute information requirements but do not form the only acceptable set of information. A licensee may depart from or omit these items, provided that the departure or omission is identified and justified in the Integrated Assessment. In addition, these items do not relieve a licensee from any requested information described in Part 2, Integrated Assessment, of the March 12, 2012, 10 CFR 50.54(f) letter, Enclosure 2.

Open Item No.	Staff Assessment Section No.	Subject to be Addressed
1	3.2.2	The licensee is requested to evaluate the plant response time considering a range of precipitation durations associated with the LIP flood hazard (e.g., 1-, 6-, 12-, 24-, 48-, 72-hour PMPs). This evaluation should identify potentially limiting scenarios with respect to plant response when considering flood height, relevant associated effects, and flood-event duration parameters.
2	3.2.5	The licensee is requested to resolve the staff-identified numerical modeling issue associated with the LIP flood analyses, specifically the reduction of volume of outflow runoff as compared to the inflow precipitation, accounting for infiltration. This issue may relate to runoff from rooftops being removed from the numerical model domain rather than discharging to the ground surface near the structure or an adjacent area.

Figure 2.2.4-1 Flood Event Duration

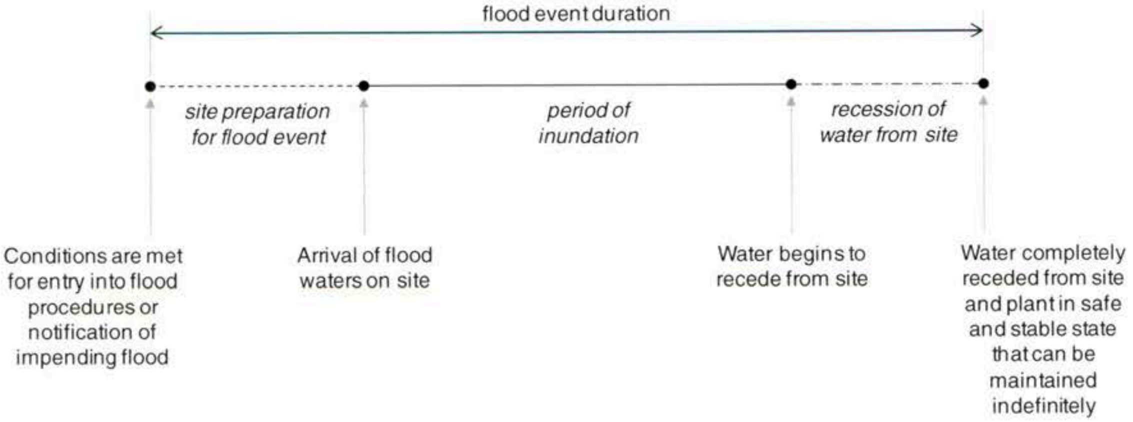
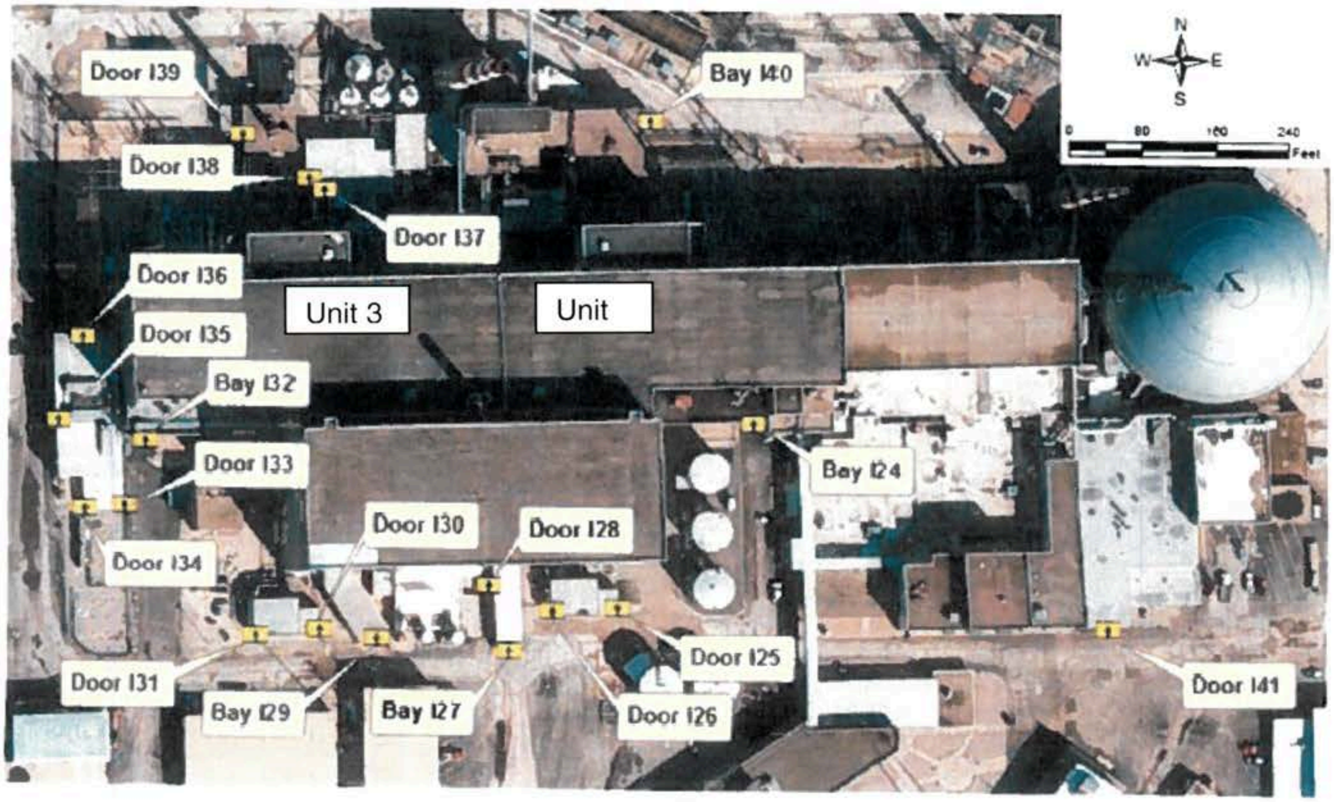


Figure 3.2.6-1 Locations of Critical Doors and Bays



If you have any questions, please contact me at (301) 415-2915 or e-mail at Victor.Hall@nrc.gov.

Sincerely,

/RA/

Victor Hall, Senior Project Manager
Hazards Management Branch
Japan Lessons-Learned Division
Office of Nuclear Reactor Regulation

Docket Nos. 50-237 and 50-249

Enclosure:
Staff Assessment of Flood Hazard
Reevaluation Report

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