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

September 25, 2015

Mr. David A. Heacock
President and Chief Nuclear Officer
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Innsbrook Technical Center
5000 Dominion Blvd.
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SUBJECT: NORTH ANNA POWER STATION, UNITS 1 AND 2 – STAFF ASSESSMENT OF RESPONSE TO 10 CFR 50.54(f) INFORMATION REQUEST – FLOOD-CAUSING MECHANISM REEVALUATION (TAC NOS. MF1106 AND MF1107)

Dear Mr. Heacock:

The purpose of this letter is to transmit the U.S. Nuclear Regulatory Commission's (NRC's) staff assessment of the re-evaluated flood-causing mechanisms described in the March 11, 2013 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML13074A925), flood hazard reevaluation report (FHRR) submitted by Virginia Electric and Power Company (the licensee) for North Anna Power Station, Units 1 and 2 (North Anna), as well as supplemental information resulting from requests for additional information. The letter also addresses the flood hazard information and the next steps associated with the mitigating strategies assessment (MSA) with respect to the reevaluated flood hazard.

By letter dated March 12, 2012, the 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.

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 Enclosure 2, Required Response 2, of the 50.54(f) letter. This closes out the NRC's efforts associated with TAC Nos. MF1106 and MF1107.

The NRC staff has concluded that the licensee's reevaluated flood hazard information, as summarized in the enclosed staff assessment is suitable for the assessment of mitigating strategies developed in response to Order EA-12-049 (i.e., defines the mitigating strategies flood hazard information described in guidance documents currently being finalized by the industry and NRC staff) for North Anna. Further, the staff has concluded that the licensee's reevaluated flood hazard information is a suitable input for other assessments associated with Near-Term Task Force Recommendation 2.1 "Flooding."

Nuclear Energy Institute (NEI) 12-06 "Diverse and Flexible Coping Strategies (FLEX) Implementation Guide," is currently being revised. This revision will include a methodology to perform an MSA with respect to the reevaluated flood hazards. Once this methodology is endorsed by the NRC, flood event duration parameters and applicable flood associated effects should be considered as part of the North Anna MSA. The NRC staff will evaluate the flood event duration parameters (including warning time and period of inundation) developed by the licensee during the NRC staff's review of the MSA.

The reevaluated flood hazard results for local intense precipitation, rivers and streams, and dam failure flood-causing mechanisms were not bounded by respective current plant design-basis hazards. In order to complete its response to the information requested by Enclosure 2 to the 50.54(f) letter, the licensee is expected to submit an integrated assessment or a focused evaluation, as appropriate, to address these reevaluated flood hazards, as described in NRC letter, "Coordination of Requests for Information Regarding Flooding Hazard Reevaluations and Mitigating Strategies for Beyond-Design-Basis External Events," (ADAMS Accession No. ML15174A257). This letter describes the changes in the NRC's approach to the flood hazard reevaluations that were approved by the Commission in its Staff Requirements Memorandum to COMSECY-15-0019 "Mitigating Strategies and Flooding Hazard Reevaluation Action Plan," (ADAMS Accession No. ML15153A104).

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

Sincerely,

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

Docket Nos. 50-338 and 50-339

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

NORTH ANNA POWER STATION, UNITS 1 AND 2

DOCKET NOS. 50-338 AND 50-339

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.[1] Subsequent Staff Requirements Memoranda associated with Commission Papers 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).

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).

If the reevaluated hazard for all flood-causing mechanisms is not bounded by the plant's current design-basis (CDB) flood hazard, an additional assessment of plant response is necessary, as described in the 50.54(f) letter and SECY-15-0019, "Mitigating Strategies and Flooding Hazard Reevaluation Action Plan" (NRC, 2015b). The FHRR and the responses to the associated Requests for Additional Information (RAIs) provide the flood hazard input necessary to complete this additional assessment consistent with the process outlined in SECY-15-0019 (NRC, 2015b) and the associated guidance that will be subsequently issued.

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[1] Issued as an enclosure to Commission Paper SECY-11-0093 (NRC, 2011a).

By letter dated March 11, 2013 (Dominion, 2013a), Virginia Electric and Power Company (Dominion, the licensee) provided its FHRR for North Anna Power Station (NAPS, North Anna), Units 1 and 2. The NRC staff issued RAIs to the licensee by letters dated November 26, 2013 (NRC, 2013b) and May 14, 2014 (NRC, 2014a). The licensee responded to the RAIs by letters dated December 13, 2013 (Dominion, 2013c), June 16, 2014 (Dominion, 2014b), November 13, 2014 (Dominion, 2014c), and May 11, 2015 (Dominion, 2015).

The licensee identified interim actions in Attachment 2 of its FHRR to address the reevaluated hazard. By letter dated August 23, 2013 (Dominion, 2013b), the licensee provided supplemental information on the status of interim actions.

The reevaluated flood hazard is not bounded by the plant's CDB for local intense precipitation (LIP), rivers and streams, and dam failure flood-causing mechanisms. Therefore, the NRC staff anticipates that the licensee will submit an integrated assessment or a focused evaluation, as appropriate, consistent with COMSECY-15-0019 (NRC, 2015b) and forthcoming associated guidance. COMSECY-15-0019 (NRC, 2015b) also outlines the need to confirm that mitigating strategies are not rendered ineffective by reevaluated flood hazards.

The licensee submitted a separate flooding walkdown report in response to NTTF Recommendation 2.3 (Dominion, 2012b). The NRC 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.

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

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 in which the historical data have been accumulated.

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

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

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. This includes current techniques, software, and methods used in present-day standard engineering practice.

2.2.1 Flood-Causing Mechanisms

Attachment 1 to NTTF Recommendation 2.1, Flooding (Enclosure 2 of the 50.54(f) letter) (NRC, 2012a) discusses flood-causing mechanisms for the licensee to address in the FHRR. Table 2.2-1 lists the flood-causing mechanisms that the licensee should consider. Table 2.2-1 also lists the corresponding Standard Review Plan (SRP) (NRC, 2007) section(s) and applicable interim staff guidance (ISG) documents containing acceptance criteria and review procedures.

The licensee should incorporate and report associated effects per Japan Lessons-Learned Directorate (JLD) 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. The ISG for performing the Integrated Assessment for external flooding, 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 Effect Flood

The worst flooding at a site that may result from a reasonable combination of individual flooding mechanisms is sometimes referred to as a "Combined Effect 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 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,[2] 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.

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[2] For the purposes of this staff assessment, the terms "combined effects" and "combined events" are synonyms.

If two less severe mechanisms are plausibly combined (per ANSI/ANS-2.8-1992 (ANSI/ANS, 1992)), 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 SG 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 site. It begins when conditions are met for entry into a flood procedure, or with notification of an impending flood (e.g., a flood forecast or notification of dam failure), and includes preparation for the flood. It continues during the period of inundation, and ends when water recedes from the site and the plant reaches a safe and stable state that can be maintained indefinitely. Figure 2.2-1 illustrates flood event duration.

2.2.5 Actions Following the FHRR

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

- Submit an Interim Action Plan with the FHRR documenting actions planned or already taken to address the reevaluated hazard(s)
- Perform an Integrated Assessment subsequent to the FHRR to (a) evaluate the effectiveness of the CLB (i.e., flood protection and mitigation systems), (b) identify plant-specific vulnerabilities, and (c) assess the effectiveness of existing or planned systems and procedures for protecting against and mitigating consequences of flooding for the flood event duration

If the reevaluated flood hazard is bounded by the CDB flood hazard for all flood-causing mechanism at the site, licensees are not required to perform an Integrated Assessment at this time.

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 current design-basis flood will not be required to complete an integrated assessment. These licensees will instead assess the impact of the LIP hazard on their sites and then evaluate and implement any necessary programmatic, procedural or plant modifications to address this hazard exceedance. In addition, for all mechanisms exceeding the CDB, licensees can assess the impact of the reevaluated hazard on their sites and confirm the capability of existing or proposed flood protection to address the hazard exceedance in lieu of performing a revised integrated assessment (NRC 2015b). Sites with flooding hazards other than LIP exceeding the design-basis flood and where the exceedance will not be addressed through existing or proposed flood protection will proceed to performing a revised integrated assessment.

3.0 TECHNICAL EVALUATION

The NRC staff reviewed the information provided for the flood hazard reevaluation of NAPS, Units 1 and 2. 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.

To provide additional information in support of the summaries and conclusions in the NAPS, Units 1 and 2 FHRR (Dominion, 2013a), the licensee made several calculation packages available to the staff via an electronic reading room. When the staff relied directly on any of these calculation packages in its review, they or portions thereof were docketed, and 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 NRC staff requested additional information from the licensee to supplement the FHRR. The licensee provided the additional information by letters dated December 13, 2013 (Dominion, 2013c), June 16, 2014 (Dominion, 2014b), November 13, 2014 (Dominion, 2014c), and May 11, 2015 (Dominion, 2015), which are discussed in the appropriate sections below.

Vertical Datums

Elevations in this staff assessment are given with respect to the National Geodetic Vertical Datum of 1929 (NGVD29). Certain elevation measurements shown in the FHRR were made with respect to the National Geodetic Vertical Datum of 1988 (NGVD88), but were converted to NGVD29 for purposes of discussion.

3.1 Site Information

The 50.54(f) letter included the SSCs important to safety, and the Ultimate Heat Sink (UHS),[3] 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 NAPS, Units 1 and 2 FHRR (Dominion, 2013a). Enclosure 2 (NTTF Recommendation 2.1: Flooding), "Requested Information, Hazard Reevaluation Report," Item a, describes site information to be contained in the FHRR. The NRC staff reviewed and summarized this information as follows.

3.1.1 Detailed Site Information

The plant grade at the powerblock is elevation 271.0 ft (82.60 m) NGVD29. The powerblock consists of the Units 1 and 2 reactors, the Turbine Building, and related structures central to the

[3] The UHS is a facility that absorbs heat as needed for safe shutdown of a nuclear reactor, to maintain it in a safe condition, and to remove heat from radioactive decay while the reactor is shut down. At NAPS, the UHS consists of the North Anna Reservoir and the Service Water Reservoir.

operation of the plant. Table 3.1-1 provides the summary of controlling reevaluated flood-causing mechanisms, including associated effects, which the licensee computed to be higher than the powerblock elevation.

The FHRR described the site-specific information related to the flood hazard reevaluation. The following is a summary of this information.

The North Anna site is located on Lake Anna in Louisa County, in northeastern Virginia. The topography in the region is typical of the central Piedmont Plateau, with a gently undulating land surface varying in elevation from about 200 ft (60 m) to 500 ft (150 m) NGVD29. The surrounding region is covered with forest and brushwood interspersed with occasional farmlands.

The plant is on a peninsula of the southern shore of Lake Anna (Figure 3.1-1). The plant property comprises 1803 acre (7,296,000 m^2), of which about 760 acre (3,100,000 m^2) is covered by reservoir and lake water. Areas within the plant property of primary interest with respect to flood hazard are:

- The Protected Area, the completely paved area inside the security fence. The interior of the Protected Area is also referred to as the "yard."
- The West Basin, a depressed area of about 0.5 acre (2,000 m^2) inside the Protected Area. The West Basin is located between the West Dike and the west end of the Turbine Building. Local intense precipitation flooding in the West Basin is discussed separately from flooding in the remainder of the Protected Area.
- The Service Water Reservoir, about 500 ft (150 m) south of the Protected Area.

Lake Anna is formed by the North Anna Dam, an earth dam about 5 mi (8 km) southeast from the plant site, which impounds the North Anna River (Figure 3.1-2). The watershed area above the North Anna Dam is about 250 mi^2 (650 km^2). The lake has an area of 13,000 acre (52,000,000 m^2) and a greatest length of about 17 mi (27 km). The lake is divided into two parts by dikes: North Anna Reservoir and Waste Heat Treatment Facility. The North Anna Reservoir (9,600 acre (38,900,000 m^2)) supplies water for plant condenser cooling. The Waste Heat Treatment Facility (3,400 acre (13,800,000 m^2)) receives heated cooling water from the plant by way of the Discharge Canal, and discharges cooled water back to the North Anna Reservoir near the dam.

The drainage area of Lake Anna is approximately 343 mi^2 (888 km^2). Many streams drain into the lake, but only two streams with a total area of about 46 mi^2 (119 km^2) have been gaged. As historical inflows to the lake are not accurately known, the licensee estimated inflows to the lake in the ESP application for the proposed NAPS Unit 3 (Dominion, 2006) and in the Updated Final Safety Analysis Report (UFSAR) for Units 1 and 2 (Dominion, 2011). Inflows were estimated indirectly using the recorded flows at the Doswell stream gaging station, the downstream gaging station nearest to the lake, located about 15 mi (24 km) downstream. The licensee adjusted the estimated outflows by the regulated releases from the lake based on the lake regulation schedule (Dominion, 2006).

The licensee provided information on site layouts and features of the safety-related structures and the UHS systems in relation to the flood reevaluation. The licensee referred further detailed descriptions of the plant facilities to the ESP Application for the proposed Unit 3 (Dominion, 2006), the UFSAR for Units 1 and 2 (Dominion, 2011), and the Final Safety Analysis Report for the Combined License Application for Unit 3 (Dominion, 2012a).

3.1.2 Design Basis Flood Hazards

The CDB flood levels for NAPS, Units 1 and 2 are described in Section 1.2 of the NAPS, Units 1 and 2 FHRR (Dominion, 2013a). The CDB flood levels are summarized by flood-causing mechanism in Table 3.1-2.

3.1.3 Flood-related Changes to the Licensing Basis

The NAPS, Units 1 and 2 FHRR (Section 1.3) stated that there have been no flood-related changes to flood protection measures beyond those in place for the CDB (Dominion, 2013a).

3.1.4 Changes to the Watershed and Local Area

The NAPS, Units 1 and 2 FHRR (Section 1.4) stated that, other than minor natural or man-made changes to stabilize the river channel, there are no significant changes to the watershed or the rivers or streams in the vicinity of the site after the licensing and operation of NAPS, Units 1 and 2 (Dominion, 2013a). The FHRR noted that the major designated growth centers in the region are not located within the Lake Anna watershed. The development near the lake has been limited only to small residential development. The impact of the residential growth on the basin runoff volume is negligible because the percentage of residential area within the basin remains small.

The primary site change pertinent to evaluating onsite LIP flooding is the installation of the concrete vehicle barriers around the powerblock area, which occurred after licensing and operating the NAPS, Units 1 and 2. The licensee analyzed the effects of these barriers on LIP flooding as described in Section 3.2 of this staff assessment.

3.1.5 Current Licensing Basis Flood Protection and Pertinent Flood Mitigation Features

The NAPS, Units 1 and 2 FHRR (Section 1.5) described the following CLB flood protection and mitigation features (Dominion, 2013a).

Flooding from Lake Anna

For flooding events in Lake Anna, the licensee implemented the following extra flood protection measures even though the predicted probable maximum flood (PMF) lake level is lower than the plant grade:

- The West Dike, a flood protection dike west of the Turbine Building, provides additional protection from high lake levels.
- A drain pipe with closure valve within the West Dike drains water from the West Basin to Lake Anna.
- The drain valve will be closed if the lake level exceeds elevation 252 ft (76.8 m) NGVD29 to prevent reverse flows from the lake to the site.
- At a reservoir level above 256 ft (78.0 m) NGVD29, Units 1 and 2 will be manually shut down and the circulation water valves closed to prevent flooding from the West Basin into the Turbine Building basement in the event of a failure of the circulation water system pressure boundary.
- The Abnormal Procedure 0-AP-40 initiates actions to protect the plant when the lake levels exceed 254 ft (77.4 m) NGVD29.

Flooding from LIP

The NAPS, Units 1 and 2 FHRR (Section 1.5.2) stated that the yard is designed and constructed to drain onsite flooding using site grading and the yard storm and sanitary sewer system. The yard storm and sanitary sewer system is designed for a storm of 10-yr frequency, 5-min duration, and rate of 7 in/h. The FHRR (Section 1.5.2) stated that the installation of the vehicle barrier system after the plant construction has limited the ability of water to leave the site by surface runoff. The licensee's reevaluation considered the effects of vehicle barriers as part of the LIP flooding hazard analysis.

The area west of the Protected Area receives runoff from an area of approximately 35 acre (140,000 m^2) (This area is discussed below as Subbasin U3 in Section 3.2.2.). The drainage swales, ditches, and culverts in this area are designed for 50-year storms.

Flooding in the West Basin

The West Basin can accumulate water along the west wall of the Turbine Building. The Turbine Building is protected against entry of this water up to elevation 257 ft (78.3 m). Internal protection from flooding of areas in the building that contain safety-related equipment is also provided by dike-type barriers up to elevation 257 ft (78.3 m). Estimated maximum water level from flooding in the West Basin is 256.1 ft (78.06 m) NGVD29; thus, internal barriers have a freeboard of 0.9 ft (0.3 m).

Flooding from the Service Water Reservoir

The licensee addressed, as a design-basis event, the potential failure of the Service Water Reservoir by overflowing or breaching. The NAPS, Units 1 and 2 FHRR (Section 1.5) states that the Service Water Reservoir was designed with an Emergency Dike and Intercepting Channel. The FHRR also states that the Emergency Dike and the Intercepting Channel were designed and constructed to prevent overflowed or breached water from flooding plant facilities for Units 1 and 2.

Other Flood Mitigation Features

The NAPS, Units 1 and 2 FHRR stated that several water level detection systems were placed throughout the Turbine Building and Auxiliary Building for detecting internal flooding, but are not credited for protection from external flooding.

3.1.6 Additional Site Details to Assess the Flood Hazard

The licensee provided electronic copies of the input files related the flood hazard reevaluations in response to RAI 3.2-2 (Dominion, 2013c).

Section 2.4.2.2 of the NAPS, Units 1 and 2 UFSAR (Dominion, 2011) discusses the flood design considerations for safety-related facilities, including the NAPS, Units 1 and 2 reactor containments, turbine buildings, auxiliary building, Service Water Reservoir, and Lake Anna Reservoir.

The sources of service water for NAPS, Units 1 and 2 are the North Anna Reservoir and the Service Water Reservoir. These two independent sources provide makeup water for the UHS for NAPS (Dominion, 2011, Section 9.2.1). The Service Water Reservoir is adequate to provide sufficient cooling for at least 30 days to allow simultaneous safe shutdown and cooldown of Units 1 and 2 in a safe-shutdown condition (Dominion, 2011, Section 9.2.5). After 30 days, makeup to the Service Water Reservoir is provided from the Lake Anna Reservoir, as necessary, to maintain cooling water inventory, ensuring a continued cooling capability.

3.1.7 Results of Plant Walkdown Activities

The 50.54(f) letter[4] 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[5] asked the licensee to report any relevant information from the results of the plant walkdown activities.

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[4] Enclosure 4, Requested Actions, Item 1 and Enclosure 4, Requested Information, Item 2.

[5] Enclosure 2, Requested Information, Items 1.a.vi and 1.c; Enclosure 2, Attachment 1, Steps 1 and 6; Enclosure 4, Requested Actions, Item 5; Enclosure 4, Requested Information, Items 1.c and 2; and Enclosure 4, Required Response, Item 2.

By letter dated November 27, 2012 (Dominion, 2012b), the licensee submitted the Flooding Walkdown Report for NAPS, Units 1 and 2. The NRC staff prepared a staff assessment Report, dated June 19, 2014 (NRC, 2014b), to document its review of the walkdown report.

The NRC staff concluded that the licensee's walkdown method and results meet the intent of the walkdown guidance. The NRC staff also concludes that the licensee, through the implementation of the walkdown guidance activities and, in accordance with plant processes and procedures, verified the plant configuration with the current flooding licensing basis; addressed degraded, nonconforming, or unanalyzed flooding conditions; and verified the adequacy of monitoring and maintenance programs for protective features. Furthermore, the licensee's walkdown results, which were verified by the NRC staff's inspection, identified no immediate safety concerns.

3.2 LIP and Associated Site Drainage

The NAPS, Units 1 and 2 FHRR reported that the reevaluated PMF elevations, including associated effects, for LIP and associated site drainage in the following areas are:

- Protected Area outside the West Basin, from 271.3 ft (82.69 m) to 274.5 ft (83.67 m) NGVD29
- West Basin, greater than 257.0 ft (78.33 m) NGVD29

Locations of these areas are shown in Figure 3.1-1 and Figure 3.1-3.

The FHRR also discussed the LIP flooding of the Independent Spent Fuel Storage Installation (ISFSI) area. However, the staff excluded the review of flooding of the ISFSI area from this staff assessment because the ISFSI area has its own license issued under the Part 72 of 10 CFR, and is not part of the 50.54(f) information request.

This flood-causing mechanism is described in the licensee's CDB presented in the Units 1 and 2 UFSAR (Dominion, 2011). The CDB maximum flood elevations for LIP and associated site drainage hazard are "no accumulation" (that is, ground elevation) at the Protected Area, and 256.1 ft (78.06 m) NGVD29 elevation at the West Basin.

Flows from the Protected Area outside the West Basin can exit through the vehicle barrier system and run in the western, southern, and eastern directions. Concerns in this area are associated with the capacity for site drainage to route rainfall away from plant structures.

The West Basin is a 0.5 acre (2,000 m^2) depression west of the Turbine Building within the Protected Area. The West Basin is subject to significant accumulation and ponding of water. At a sufficient depth, water from the West Basin can flow into the Turbine Building basement.

3.2.1 Local Intense Precipitation

The licensee estimated up to 6-hour onsite PMP values in the Final Safety Analysis Report for the Combined License Application for the proposed Unit 3 (Dominion, 2012a). The licensee's 6-hour PMP depth is 27.9 in (70.9 cm), while 1-hour PMP depth is 18.3 in (46.5 cm). These PMP values are based on the guidance in HMR 51 (NOAA, 1978) and HMR 52 (NOAA, 1982). The staff confirmed these values earlier in the review of the Unit 3 site, as documented in the Safety Evaluation Report for an Early Site Permit at the North Anna site (NRC, 2005, Chapter 2). Because neither the present standard methods nor values associated with estimating the PMP have been changed since the licensee's PMP estimation in 2005, the licensee determined that the previous PMP values are valid for the reevaluation. The licensee estimated incremental PMP intensities up to 6-hour duration and distributed temporally in the rainfall-runoff model, with the highest intensity occurring at the storm center and the next highest intensities being distributed on either side of the peak intensity.

The NAPS, Units 1 and 2 FHRR (Section 2.1.2) stated that the 72-hour PMP depth was used to determine the runoff volume into the West Basin because the overall precipitation depth and runoff volume for a 72-hour storm are conservatively greater than those of a 6-hour PMP (Dominion, 2013a). The FHRR obtained a 72-hour, 10 mi^2 (26 km^2) PMP depth of 43 in (109 cm) using the guidance in HMR 51 (NOAA, 1978).

3.2.2 Runoff Analyses

The licensee chose to use the hierarchical flood hazard assessment approach described in NUREG/CR-7046 (NRC, 2011e). The NRC staff performed a systematic review of how the site conceptual model discussed in the FHRR was implemented. For modeling runoff, the licensee used two numerical models from the U.S. Army Corps of Engineers (USACE) Hydrologic Engineering Center: the Hydrologic Modeling System (HEC-HMS) (USACE, 2010b), and the River Analysis System (HEC-RAS) (USACE, 2010a).

The licensee used HEC-HMS to evaluate runoff and hydrologic routing for each of the three areas. The licensee delineated 22 subbasins covering all three areas, 1 reservoir (named "Reservoir U3") located west of the Protected Area within Subbasin U3 (Figure 3.2-1), 9 junctions that combine the node-link (subbasin-junction) schematic of the subbasins and the reservoir, and a diversion. There are no onsite drainage ditches within the Protected Area. The vehicle barriers with a height of 32 in (81 cm) on the west side of the Protected Area are located at the bottom of the western hill slope, while those on the north side act as a retaining wall. Considering these surficial configurations, the Protected Area was divided into four overland flowpaths to either west or east.

The NRC staff reviewed the FHRR and RAI responses related to LIP flood analyses. The staff also checked licensee-provided maps showing high-resolution site layout with ground surface elevation contours as well as subbasins and flowpaths used for the LIP modeling. The NRC staff noted that the Protected Area outside the West Basin was graded for onsite drainage. The NAPS, Units 1 and 2 FHRR Figures 2.1-2 through 2.1-4 provide the detailed maps showing flowpaths as well as the locations of cross sections used in the licensee's LIP HEC-RAS modeling (Dominion, 2013a). The NRC staff noted that a significant fraction of the Protected Area is covered with buildings. The staff found that the licensee included buildings and the vehicle barrier system when developing the numerical model of the site, and reasonably delineated subbasins, subbasin interconnections, and flowpaths.

The licensee used the Natural Resources Conservation Service (NRCS) option (also called the SCS (Soil Conservation Service) unit hydrograph method) in HEC-HMS to model the rainfall-runoff process in each subbasin. As the subbasins within the Protected Area are mostly impervious, the licensee assigned a runoff curve number of 98 (SCS, 1986) which produce conservatively high flow rates. Even for the unpaved area, the selected curve number meets a saturated soil condition from an antecedent rainfall as recommended by ANSI/ANS-2.8 (ANSI/ANS, 1992). On each subbasin, the licensee used the Engineer Manual EM 1110-2-1417 guidance (USACE, 1994) to estimate peak runoff and NRCS guidance implemented in HEC-HMS (USACE, 2010b) to obtain time to peak. To account for non-linear runoff response for large storms, the licensee adopted a 25-percent reduction of the estimated time of concentration. The licensee also assumed lag times equal to 0.6 times the time of concentrations.

The licensee's LIP flood reevaluation considered antecedent rainfall conditions in its LIP flood analysis according to NUREG/CR-7046 (NRC, 2011e). The Protected Area is a nearly flat, impervious surface; therefore there would be no potential for significant hydraulic jumps or scour. The licensee also assumed that rainfall contributes runoff without significant losses by infiltration or evaporation.

The licensee's RAI response (Dominion, 2013c) stated that all roof drain features (e.g., scuppers, gutter outlets, etc.) are assumed to be clogged or non-functional (but opened through the lower parts of parapets) during the PMP events, and that roof runoff is accounted for in the model by assuming that building roofs are impervious with no detention or delay of runoff from roofs. That is, roof runoff is accounted conservatively in the HEC-HMS model by combining the surface area of the roof with the ground surface area in each subbasin without separate routing of the roof areas. Specifically, the NAPS, Units 1 and 2 FHRR (Section 2.1.2) stated that the Turbine Building roof has 2 ft (0.6 m) high parapet walls on the north, east, and south sides and a 6 in (15 cm) high wall on the west. Because of this parapet feature, the runoff from the Turbine Building roof drains only to the west parapet wall, and then to the West Basin (Dominion, 2013a).

The NRC staff focused its review on the modeling of Subbasin-CW1 (e.g., upper central west subbasin in the powerblock area as shown in Figure 3.1-3), because the maximum LIP flood level occurs on this subbasin. This subbasin covers half of the Control Building, half of the Unit 2 Reactor, and the open grade area between these two buildings (marked in green in Figure 3.1-3). The Turbine Building is attached to the north side of the Control Building, and the elevation of the Turbine Building roof is higher than that of the Control Building roof. In its review of the FHRR and RAI response, the staff raised to the licensee a question that a portion of the runoff from the Turbine Building roof could flow to the Subbasin-CW1 if there were drain holes on the south side of the Turbine Building roof. The licensee confirmed that there are no roof drain holes on the south side of the Turbine Building roof, resolving the staff's question related to the Turbine Building roof runoff (Shaub, 2014).

The node labeled "Reservoir-U3" in the HEC-HMS simulation represents the large excavated area for the proposed Unit 3 located west of the Protected Area (Figure 3.2-1). This surface depression can drain directly to Lake Anna via a 14 ft (4.3 m) x 14 ft (4.3 m) culvert. Two flowpaths, from the Protected Area and Subbasin U3, drain into Reservoir-U3. The FHRR provided stage-area and stage-discharge relationships for Reservoir-U3. To build the stage-discharge relationship, the licensee assumed that the lower half of the culvert is blocked with debris and that the exit of the culvert is submerged by Lake Anna at 265 ft (80.8 m) NGVD29.

The node labeled "SBO [station blackout] Bowl Diversion"[6] in HEC-HMS represents diversion of runoff to the West Basin. If the depth of the flow increases above a certain level in a flowpath leading from the Protected Area to Reservoir-U3, a portion of the flow will enter the West Basin. The NAPS, Units 1 and 2 FHRR stated that the portion of flow entering the West Basin from this pathway was estimated using a diversion rating curve for the portion of flow that is diverted from the flowpath to the West Basin (Dominion, 2013a). The drain from the West Basin to Lake Anna is assumed to be fully blocked. Because the West Basin is presumed to be unable to drain, the licensee determined that a longer duration PMP could produce more significant floods. For instance, the 72-hour PMP would result in 43 in (109 cm) of runoff entering the West Basin compared to 28 in (71 cm) of runoff for the 6-hour PMP. Based solely on the estimated volume of runoff and the combined storage volumes for the West Basin and the Turbine Building basement, the licensee determined that the 72-hour PMP would not overtop the flood protection wall internal to the Turbine Building.

The NAPS, Units 1 and 2 FHRR (Table 2.1-7) summarized results of the LIP flood analysis, including peak discharges, time to peaks, and runoff volumes by subbasin or junction (Dominion, 2013a). The high volumes and high peak discharges for model nodes Subbasin-U3, and Reservoir-U3 are consistent with their large drainage areas.

The staff reviewed the NAPS, Units 1 and 2 FHRR and RAI responses, including the HEC-HMS input and output files provided by the licensee (Dominion, 2013c), and performed simple sensitivity analyses with the licensee's model. The staff noted that the assumptions are conservative (e.g., complete blockage of all drains, except the box culvert that drains Reservoir U3 into Lake Anna), and that the postulated PMP events with a 6-hour duration at the Protected Area and a 72-hour duration at the West Basin generate conservative runoffs in their respective analyses. The staff found that the HEC-HMS implementation was consistent with the conceptual model discussed in the FHRR.

3.2.3 Water Level Determination

The licensee used HEC-RAS (USACE, 2010a) to evaluate water levels in the Protected Area outside the West Basin. The licensee developed flowpaths and channel cross-sections by using LIDAR and spot-surveyed elevations. The subbasin outflow hydrograph simulated with the HEC-HMS model was used as a respective channel upstream inflow hydrograph in the HEC-

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[6] "SBO Bowl" is an alternative name for the West Basin. It is used because the Station Blackout Building is located inside the West Basin.

RAS model. For the West Basin, the licensee estimated the water elevations using HEC-HMS with the stage-area and stage-discharge rating curves.

The NRC staff reviewed the NAPS, Units 1 and 2 FHRR and RAI responses (Dominion, 2013c), including the HEC-RAS files provided by the licensee. The NRC staff reviewed the HEC-RAS numerical model to ensure that the model was implemented in a manner consistent with the single (6-hour PMP) deterministic conceptual model described in the FHRR, and that both explicit and implicit assumptions in the analysis were defensibly justified. The NRC staff also reviewed the sensitivity analysis of the HEC-RAS model with five steady-state upstream inflow scenarios.

The NRC staff found that the HEC-RAS implementation was consistent with the conceptual model discussed in the NAPS, Units 1 and 2 FHRR. The NRC staff's review found that the licensee used reach-specific input values at several cross sections in order to avoid unrealistic supercritical flow conditions. As a result, the FHRR stated that hydraulic jumps do not occur. The FHRR stated that a Manning's roughness coefficient of 0.018 is used to represent the condition of asphalt surface in the Protected Area. The NRC staff performed a perturbation test by increasing the expansion and contraction coefficients for openings on barriers and noted that the results are insensitive to these coefficients.

The reevaluated flood elevations caused by a postulated LIP event in the Protected Area outside the West Basin and the West Basin exceed the respective CDB levels. In the Protected Area, maximum LIP flood level occurs at the open area between Unit 2 Reactor and the Control Building.

Because the fetch length is short and water depth is small, the NRC staff determined that the wind impacts on LIP flooding are not applicable. The NRC staff noted that the hydrodynamic loads induced by the current velocity of LIP floods are not of concern because the direction of the flow is away from the building structures and doors. The NRC staff also determined that other associated effects on LIP flooding, including effects of erosion and sedimentation, adverse weather conditions, and groundwater ingress, are not of concern at the site.

3.2.4 Conclusion

The NRC staff confirmed the licensee's conclusion that the reevaluated flood hazard for LIP and associated site drainage is not bounded by the CDB flood hazard; therefore, staff expects that the licensee will submit a focused evaluation for LIP and associated site drainage consistent with COMSECY-15-0019 (NRC, 2015b).

3.3 Streams and Rivers

The NAPS, Units 1 and 2 FHRR (Dominion, 2013a) reported that the reevaluated PMF elevation, including associated wind effects, for stream and river floods is 267.42 ft (81.510 m) NGVD29. This flood-causing mechanism is described in the licensee's CDB. The corresponding CDB hazard for site flooding from streams and rivers with wind effects is 267.3 ft (81.47 m) NGVD29 (Dominion, 2011, Section 2.4.3.6).

The licensee used the HEC-HMS model (USACE, 2010b) to evaluate river PMF. The modeling approach is similar to that of the earlier ESP analysis (Dominion, 2006), which used the USACE's HEC-1 model. This model is a predecessor of HEC-HMS. The licensee used HEC-HMS to simulate the surface runoff response of the North Anna River basin to a 72-hour PMP scenario, as discussed below.

The NRC staff requested additional information from the licensee to supplement the FHRR (NRC, 2013b). The licensee provided the additional information (Dominion, 2013c; Dominion, 2014b; and Dominion, 2014c), which is discussed below.

3.3.1 Probable Maximum Precipitation and Losses

For the Unit 3 licensing, the licensee estimated up to 72-hour duration PMP values based on the size and shape of the Lake Anna drainage basin (Dominion, 2006; Dominion, 2012a). The estimation was based on the guidance in HMRs 51, 52, and 53 (NOAA, 1978; NOAA, 1982; NOAA, 1980). The FHRR (Section 2.1.2) stated that a review of historical precipitation records for central Virginia had identified no events approaching or exceeding the PMP provided in HMRs 51, 52, and 53. Therefore, the licensee applied the same Unit 3 PMP values in the FHRR. The NRC staff reviewed of these PMP values is documented in its review of the ESP application (NRC, 2005, Chapter 2).

The licensee adopted the same precipitation loss coefficients that were used for the ESP application, except for a change in definition of loss coefficient ratio in HEC-HMS. The NRC staff confirmed these loss coefficients in its review of the ESP application (NRC, 2005, Chapter 2). The NRC staff determined in its review of the FHRR, that neither the present methods nor values associated with estimating precipitation loss have changed since the staff's ESP review.

3.3.2 Hydrology and Hydraulic Modeling

The licensee used the HEC-HMS model in its reevaluation of the river PMF flow rates. NUREG/CR-7046 (NRC, 2011e) recommends a 30 percent reduction in the time to peak; however the licensee has chosen to adopt an even more conservative 50 percent reduction. The NRC staff found, based on a review of the input and output files for the HEC-HMS model that the HEC-HMS implementation was generally consistent with the conceptual model discussed in the FHRR.

The licensee determined the PMF flood levels on the Lake Anna caused by a basin PMP event. The licensee used the PMF inflow hydrograph estimated from the HEC-HMS model as an upstream input, and then calculated lake levels at the Lake Anna Dam based on a level pool assumption and stage-discharge relationship at the Lake Anna dam. They obtained plant-site lake levels by adding a backwater effect of 0.2 ft (0.06 m) as described in the UFSAR (Dominion, 2011, Section 2.4.3.5). The NRC staff confirmed during the ESP review that the lake stage-discharge relationship, which is the most critical component in determining the lake flood levels, is accurate (NRC, 2005).

3.3.3 Coincident Wind Wave Activity

The FHRR used a wind setup of 0.09 ft (0.03 m) and a wind wave runup of 3.03 ft (0.924 m) for Lake Anna near the vicinity of the plant site. These values were adopted from the Early Site Permit Site Safety Analysis Report (Dominion, 2006). The NRC staff previously reviewed these wave effect values during its review of the ESP application (NRC, 2005). For the FHRR review, the NRC staff determined that the previous review is still valid because neither the present standard of methods nor values associated with estimating coincident wave activity has changed since the staff's ESP review.

The NRC staff reviewed the FHRR and RAI response (Dominion, 2013c) related to flooding in rivers and streams. For the FHRR, the licensee modified the ESP PMF analysis to reflect a potential increase in the target normal pool elevation by 3 in (8 cm). The licensee's PMF level with wind effect would be 267.4 ft (81.50 m) NGVD29, which is 0.1 ft (0.03 m) higher than the design basis PMF water level.

3.3.4 Conclusion

The NRC staff confirmed the licensee's conclusion that the reevaluated hazard from flooding from streams and rivers is not bounded by the CDB flood hazard. Therefore, the NRC staff anticipates that the licensee will submit a focused evaluation confirming the capability of flood protection and available physical margin or a revised integrated assessment, consistent with COMSECY-15-0019 (NRC, 2015b).

3.4 Failure of Dams and Onsite Water Control/Storage Structures

The FHRR reported that the reevaluated flood hazard, including associated effects, for failure of upstream dams from the North Anna River results in a stillwater-surface elevation on Lake Anna of 264.7 ft (80.68 m) NGVD29. Flood hazard from failure of the Service Water Reservoir and the Emergency Dike was also discussed in the FHRR and the response to RAIs. This potential flood-causing mechanism was reviewed and screened out in the licensee's CDB, as it was concluded that there is no risk of flooding from this mechanism (Dominion, 2011, Section 2.4.4).

The NRC staff requested additional information from the licensee to supplement the FHRR (NRC, 2013b). The licensee provided the additional information (Dominion, 2013c; Dominion, 2014b; Dominion, 2014c; and Dominion, 2015), which is discussed below.

3.4.1 Dam Failure Flooding in North Anna River

The surface area of Lake Anna, including Lake Anna Reservoir and the Waste Heat Treatment Facility, is 19,400 acre (78.5 km^2) at the stillwater PMF water level of 264.3 ft (80.56 m). The FHRR analyzed the effects of flooding caused by a postulated upstream dam failure scenario on the North Anna River. This analysis identified two large upstream reservoirs: Lake Louisa and Lake Orange (Figure 3.1-2). The licensee assumed simultaneous failure of these two dams. As part of a screening analysis, the licensee conservatively assumed that the water from the two reservoirs at their full capacities was translated directly and instantly to Lake Anna without loss. This analysis estimated an increase in Lake Anna water level of about 0.4 ft (0.1 m) above the

PMF water level. The licensee's reevaluated lake flood level for a combined effect of river PMF and dam failure is 267.4 ft (81.50 m) NGVD29 or 267.8 ft (81.63 m) NGVD29 with wind effects. Since these flood levels are all below the plant grade, the licensee concluded that there is no credible risk of flooding or other impacts to the safety-related function of the plant due to the failure of these upstream dams with associated effects.

The NRC staff also performed a conservative dam failure flooding analysis for the North Anna River basin. First, the NRC staff obtained the dam information from the latest National Inventory of Dams database (USACE, 2013). The NRC staff identified a total of 11 upstream dams within the Lake Anna basin. A total combined storage volume of these dams is 10,197 acre-ft (12,577,000 m^3). The NRC staff assumed that all 11 dams would fail at their full storage capacities, and that the breach outflows move into the lake simultaneously without loss. Second, with this conservative dam failure scenario, the staff estimated an increase of the Lake Anna water level from the licensee-estimated PMF water level of 0.53 ft (0.16 m). The NRC staff's estimate of the corresponding lake level for a combination of PMF and dam failure with wind effects is 267.93 ft (81.665 m) NGVD29, which is slightly higher than the licensee's reevaluated value but still below the plant grade with about 3 ft (0.9 m) margin. Therefore, the NRC staff concurs with the licensee's conclusion that the failure of these upstream dams would not inundate the plant site.

3.4.2 Flooding from Postulated Service Water Reservoir Impounding Dike Failures

The FHRR discussed the effects of a potential failure of the Service Water Reservoir Impounding Dike.[7] The Service Water Reservoir is a safety-related facility located approximately 500 ft (152.4 m) south from the plant area (see Figures 3.1-1 and 3.4-1). The reservoir is encircled by earthen dike (the Impounding Dike), which is a Seismic Class I Structure.

The FHRR stated that the Impounding Dike system was designed and constructed to preclude overtopping, piping, sliding, and other sources of failures. For added conservatism, the slopes and crest of the dike are protected by the outer rock shell that offers erosion protection from wind wave or potential overtopping. The FHRR noted that additional protection of the plant from the flooding created by a potential dike failure is provided by an Emergency Dike and Intercepting Channel.[8] This dike-channel system was constructed on the downslope north of the reservoir to divert flood from a dike failure toward the Discharge Canal (see Figure 3.4-1). Therefore the FHRR (Section 2.3.4) concluded that "a failure of the Service Water Reservoir, though unlikely, will not impact the safe functioning of Units 1 and 2."

Because the FHRR did not describe how the licensee reached this conclusion for the Impounding Dike failure, the NRC staff requested, via RAI No. 3.4-1, information related to the

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[7] The RAI response also refers to the Impounding Dike as the impoundment dike, the service water impoundment dam, and the reservoir dike.

[8] RAI 3.4-1 also refers to the Intercepting Channel as the diversion channel, the diversion trench, and the intercepting trench.

effectiveness of the Impounding Dike as well as the Emergency Dike and Intercepting Channel system (NRC, 2013b). The licensee's response (Dominion, 2013c) to this RAI discussed three potential Impounding Dike failure modes: overtopping, piping (sunny day failure), and seismically-induced failure.

3.4.2.1 Overtopping Failure

The licensee's response to RAI 3.4-1 (Dominion, 2013c) stated that the Service Water Reservoir is sitting on a knoll, significantly above the plant (Dominion, 2013c). This knoll location prevents the possibility of local rainfall water flowing into the reservoir, so that only direct precipitation reaches the reservoir. The licensee estimated a 72-hour 10 mi^2 (26 km^2) PMP depth plus 40-precent antecedent PMP of 43 in (109 cm) or 3.58 ft (1.091 m). The reservoir was designed with approximately 5 ft (1.5 m) freeboard above the maximum reservoir operating water level. Therefore, the licensee determined that the PMP itself will not overtop the Service Water Reservoir Impounding Dike.

The staff noted from the UFSAR Section 3.8.4 (Dominion, 2011) the following design information for the Service Water Reservoir Impounding Dike:

- The reservoir has a bottom surface area of 7.9 acre (32,000 m^2) and a storage capacity of 88 acre-ft (109,000 m^3).

- The maximum operating elevation and the bottom elevation of the reservoir are 315 ft (96.0 m) and 305 ft (93.0 m) NGVD29, respectively.

- The Impounding Dike surrounding the reservoir has a length of approximately 3,000 ft (900 m). The dike was constructed of earth and rock materials while the northwest portion of the dike (approximately 500 ft (150 m)) was formed by cutting the naturally high ground.

- The areas of the dike below elevation 305 ft (93.0 m) are filled with impervious core materials with compaction.

- Immediately downstream of the impervious dike core is a transition filter zone of sand filter and coarse filter, which provides internal drainage.

- The riprap lining of the Impounding Dike (both upstream and downstream surfaces) extends up all excavated slopes to above the maximum reservoir water level.

To make a confirmatory analysis, the NRC staff estimated the wind wave effects of the licensee's PMP level in the Service Water Reservoir. The NRC staff obtained a maximum fetch length of 1,000 ft (300 m) from a detailed site layout map (Dominion, 2013c, Map 3). Using a coincident 2-year wind speed of 50 mi/h (80 km/h) (FHRR Section 2.2.6), the NRC staff estimated a wave run-up of 1.5 ft (0.46 m) using the USACE's nomograph procedure (USACE, 2003). The corresponding staff-estimated reservoir water level increase caused by a combination of PMP and wind effects is 5.08 ft (1.548 m), which slightly exceeds the dike's freeboard. However, the NRC staff determined that an overtopping failure of the reservoir dike will not occur because the depth of overflow is small and the duration of the run-up would be short (several minutes).

3.4.2.1.1 *Piping Failure*

The licensee's response to RAI 3.4-1 (Dominion, 2013c) stated that the Impounding Dike is a Seismic Class I structure, and has been evaluated to preclude overtopping, piping, sliding, and other modes of failure, and that the design of the reservoir and dike system was approached conservatively, using design procedures and methods for major earth dams, such as limit equilibrium slope stability studies for the steady-state and design-basis seismic event conditions. The response to RAI 3.4-1 stated that, for added conservatism, the slopes and crest of the Impounding Dike are protected by an outer rock shell that offers erosion protection during overtopping or a major storm.

The response also stated that the Service Water Reservoir and the Impounding Dike are safety-related structures and, as such, are required to be instrumented, inspected, and maintained consistent with the design requirements. It also mentioned that the dike has been, and will be, periodically inspected by plant engineering staff and by external agencies responsible for inspection of such structures. These inspections will identify early indications of the presence of trees, or rodent intrusion, or potential erosion areas to prevent weakening of the dike structure. Therefore, the licensee concluded that dike design considerations and dike inspection and maintenance measures preclude issues associated with Impounding Dike failure by means of piping.

A sunny-day piping failure of the Service Water Reservoir Impounding Dike cannot be screened out as described in the Interim Staff Guidance JLD-ISG-2013-01 (NRC, 2013a, p. 6-1). Therefore, the NRC staff evaluated the effectiveness of the Emergency Dike and Intercepting Channel system in protecting against flooding resulting from a potential piping failure of the Service Water Reservoir Impounding Dike.

3.4.2.2 *Capacity of the Intercepting Channel*

Because a piping failure of the Service Water Reservoir Impounding Dike seems a plausible event, the staff evaluated the effectiveness of the downstream Emergency Dike and Intercepting Channel system to divert breach outflow from the reservoir. The staff used an unsteady option of HEC-RAS (USACE, 2010a) to simulate the breach outflow in the Intercepting Channel. In this simulation, the staff assumed that the Service Water Reservoir Impounding Dike would fail by piping, but the Emergency Dike would not fail by piping because (1) the Emergency Dike is in a dry condition before intercepting the breach outflow and (2) the duration of breach outflow from the Impounding Dike is short enough (less than an hour) not to develop a full piping failure of the Emergency Dike (NRC, 2015a). With this assumption, staff evaluated the capacity of the Emergency Dike system based on the HEC-RAS unsteady simulation.

The licensee's response to RAI 3.4-1 (Dominion, 2013c) stated that a channel-dike system was built on the slope between the Service Water Reservoir and Units 1 and 2. Its purpose was to capture the potential breach outflow from the reservoir, then divert the flow eastward toward the

Discharge Canal. The Intercepting Channel has a nominal width of about 35 ft (11 m) and a total length of approximately 800 ft (240 m). The Emergency Dike forms the left bank of the channel with an average height of about 10 ft (see Figure 3.4-1).

During the site planning and design stage for the Units 1 and 2, the licensee performed a simple hydraulic analysis to size of the Intercepting Channel and Emergency Dike (Dominion, 2013c). They assumed an instantaneous 90-degree v-notch breach of the Impounding Dike, from the top to the bottom of the dike. The licensee estimated, using a simple weir equation, a breach outflow hydrograph with a peak rate of approximately 1,000 ft^3/s (30 m^3/s).

The NRC staff noted in its review of the FHRR and RAI responses, that the licensee's v-notch shape of the breach could result in an underestimation of breach outflow rates. Alternatively, the staff assumed a trapezoidal-shape dike breach with 45-degree breach slopes on both sides. The NRC staff used several regression-based breach parameter equations, and determined an average breach width (e.g., an average of top and bottom widths) of 60 ft (18.3 m) and breach time of 0.24 h (NRC, 2015a). Using the HEC-RAS dam breach option, the NRC staff simulated a breach outflow hydrograph from a breach of the Impounding Dike. The resulting peak breach outflow rate was approximately 2,800 ft^3/s (79 m^3/s). This breach outflow hydrograph was used as an upstream input to simulate the stage hydrographs along the reach of the Intercepting Channel using the HEC-RAS unsteady flow option.

The NRC staff postulated two conservative dike failure scenarios using the following assumptions:

- A dike breach would occur on the northern section of the Impounding Dike between the Pump House and the junction of the Impounding Dike and the Emergency Dike (Figure 3.4-1, Dike Breach 1). A breach only on this critical section could potentially impact the Units 1 and 2 powerblock area. In other words, a breach flood occurring from outside this critical section will not impact the plant site.

- The NRC staff selected the encroachment section of the Intercepting Channel (Figure 3.4-1, Dike Breach 2) as a potential location for overtopping or piping failure of the Emergency Dike. This is because the velocity and head of the channel flow on this section could potentially increase due to the encroachment effects, resulting in overtopping and breaching of the Emergency Dike.

The HEC-RAS model was set up to simulate the unsteady breach flow in the Intercepting Channel. From the series of the model simulations, the staff confirmed that the channel flow caused by the breach outflow from the Service Water Reservoir would not overtop the Emergency Dike (NRC, 2015a). Thus, the only scenario that could impact the Units 1 and 2 powerblock area is a combined failure of both Service Water Reservoir Impounding Dike and Emergency Dike simultaneously because of a seismic event. This scenario is addressed in the next section, which discusses the potential for seismically-induced failure of the dikes.

3.4.2.3 *Seismic Dike Failure*

By letter dated November 26, 2013 (NRC, 2013b), NRC staff issued RAI 3.4-1, which requested that the licensee provide evaluations of failure mechanisms applicable to the Service Water Reservoir impoundment using present-day guidance, methods, and data. One mechanism was seismically-induced failure of the Service Water Reservoir Impounding Dike under site-specific seismic hazards.

By letter dated December, 13, 2013, the licensee responded to RAI 3.4-1 (Dominion, 2013c) by stating that a site-specific seismic hazard reevaluation using present-day guidance and methods will be completed in March 2014 and that the "adequacy of the seismic qualification for the service water reservoir impoundment dike [Impounding Dike] may have to be revisited depending on the results of the seismic reevaluation and resulting station PRA [probabilistic risk assessment] reevaluations." The response further stated that "even if the impoundment dike [Impounding Dike] were to fail as result of a seismic event, the design of the emergency dike and the diversion trench prevent water from the service water reservoir from reaching the plant site." The RAI response did not provide information about the seismic capacity or performance of the emergency dike (which is not a Seismic Category 1 structure) to support a conclusion that it would be available in the event that the Service Water Reservoir Impounding Dike were to fail under a seismic event.

By letter dated March 31, 2014, the licensee submitted the seismic hazard and screening report (Dominion, 2014a). The report concluded that North Anna "screens in" for a seismic probabilistic risk assessment because the screening evaluation indicated that the ground motion response spectrum (GMRS) exceeds the safe shutdown earthquake.

By letter dated May 14, 2014 (NRC, 2014a), NRC issued a supplemental RAI that requested the licensee to either (a) provide justification for the seismic capability of the Service Water Reservoir Impounding Dike under the updated seismic hazard, or (b) provide a technical basis for the ability of the Emergency Dike to withstand the updated seismic hazard such that it is able to convey sufficient outflow from a postulated seismically-induced failure of the Service Water Reservoir Impounding Dike system.

By letter dated November 13, 2014 (Dominion, 2014c), the licensee responded to the supplemental RAI with an evaluation to provide justification for the seismic capability of the Service Water Reservoir under the updated seismic hazard.

By letter dated May 11, 2015 (Dominion, 2015), the licensee supplemented the information provided in the November 13, 2014 response. The supplement included:

- Tabulation of the results of shear wave velocity-based correlations for liquefaction (Youd et al., 2001) using a best-estimate shear wave velocity profile with an age factor set equal to 1.0.

- Tabulation of shear wave velocity, shear modulus, and damping information for the saprolite material.

- Summary of the results of the slope stability calculation for the Seed method (Seed, 1979).

The NRC staff reviewed the licensee's evaluations, as documented in two submittals (Dominion, 2014c; Dominion, 2015), with respect to the potential for flooding of the Units 1 and 2 powerblock as a result of seismically-induced failure of the Service Water Reservoir Impounding Dike. The NRC staff review relied upon hydraulic considerations in addition to a review of the licensee's geotechnical evaluation. For this reason, the NRC staff conclusions regarding the potential for seismically-induced flooding should not be interpreted more broadly with respect to the necessity to consider the potential for failure of the Service Water Reservoir Impounding Dike in the context of other applications (e.g., seismic probabilistic risk assessment).

The NRC staff hydraulic calculations (NRC, 2015a) confirmed that, in order to induce flooding of the powerblock as a result of failure of the Service Water Reservoir Impounding Dike, a breach must occur on a specific section of the Impounding Dike located between the Service Water Reservoir Pump House and the junction of the Impounding Dike and the Emergency Dike. Failure of other portions of the Service Water Reservoir Impounding Dike are not expected to induce flooding of the Units 1 and 2 powerblock. The NRC staff calculations also confirmed that flooding would be induced in the southeast portion of the powerblock area only if both the Service Water Reservoir Impounding Dike and the Emergency Dike failed concurrently, and if breaches were relatively large (conservatively estimated) breach sizes. These hydraulic considerations informed the staff's review of the seismic dike failure analyses.

The licensee's evaluation considered the slope stability, settlement, and cracking, as well as liquefaction and lateral spreading failure modes. The licensee's response dated November 13, 2014 (Dominion, 2014c), stated that the slope stability calculation was performed by computer analysis using the Morgenstern-Price method for seismic and non-seismic cases.

For the non-seismic case, the response established minimum acceptable factors of safety as 1.3 for undrained conditions and 1.5 for drained conditions. The licensee ran analyses for the non-seismic case for drained and undrained conditions, and the response stated that the minimum computed factor of safety for static analysis was 1.8. Because the Service Water Reservoir Impounding Dike is an existing Seismic Category 1 structure, no further staff review of the non-seismic case was performed.

For the seismic loading case slope stability evaluation, the response used a pseudo-static approach for undrained conditions and established a minimum factor of safety of 1.1. The response noted that modifications to the pseudo-static approach were used "in order to address the over-conservatism of the method." Modifications involved reduction in ground acceleration and ground strength parameters. The response noted that the computed factors of safety for dynamic analysis for the downstream slope ranged from 1.2 to 1.6, with an average factor of safety of 1.5. The computed factors of safety for the upstream slope ranged from 1.0 to 1.5, with an average factor of safety of 1.3. The response noted that instances of factors of safety below the established acceptability threshold would be associated with a potential shallow surface failure of upstream dike that would not lead to breach of the entire embankment. The computed factors of safety associated with the Seed method (Seed, 1979) are tabulated in Table 3.4-1, and are all in excess of 1.3.

The response's liquefaction evaluation used empirical correlations based on measured standard penetration test values, as well as the shear wave velocity profile (Youd et al., 2001). The response established a minimum acceptable factor of safety of 1.1. The response used an age factor of 2.0 and computed factors of safety above their defined factor of safety threshold. The staff did not find a sufficient technical basis for use of an age factor of 2.0 in the FHRR. However, supplemental information submitted by the licensee (Dominion, 2015) demonstrates that, when using a best-estimate shear wave velocity profile and the shear wave velocity-based correlations, the factors of safety remain high when the age factor is removed (i.e., set equal to 1.0). The factors of safety computed by the licensee are shown in Table 3.4-2.

The aforementioned licensee evaluations used a peak ground acceleration value of 0.28g as the input ground motion. The NRC staff was unable to come to a satisfactory conclusion regarding the input ground motions. Specifically, NRC staff did not find a sufficient technical basis for assumptions used in the site response analysis. However, increases in the input ground motion from 0.28g estimated by the licensee to 0.35g estimated by the NRC staff would not impact the computed factors of safety for slope stability analysis using the Seed method because it uses pseudostatic coefficient k_h that is a fraction of the peak crest acceleration when crest accelerations are less than 0.75g (i.e., $k_h = 0.15$ for a magnitude 8.5 event) and are thus insensitive to increases in peak ground acceleration that do not exceed 0.75g. For liquefaction potential evaluation, the results in Table 3.4-2 demonstrate that the increases in ground motion will not reduce the computed factor of safety (using best-estimate shear-wave velocity profile and shear-wave velocity-based correlations) below acceptable thresholds.

3.4.3 Conclusion

The licensee analyzed the dam failure flooding scenario caused by a potential failure of the upstream dams in the North Anna River. The NRC staff performed a confirmatory analysis of the multiple dam failure flooding in Lake Anna and agrees with the licensee's conclusion that any upstream dam failure flooding and its combined and associated effect flooding in Lake Anna would not inundate the plant site.

The licensee also evaluated the integrity of the Service Water Reservoir Impounding Dike against piping, overtopping, and seismic failure modes. The licensee's evaluation considered seismic failure modes including slope stability, settlement, cracking and resulting potential for internal erosion, as well as liquefaction and lateral spreading. The licensee concluded that failure of the Service Water Reservoir Impounding Dike is not credible. The NRC staff reviewed the licensee-provided information related to the seismic dike failure analyses in conjunction with staff hydraulic calculation and confirmed the licensee's conclusion that seismically induced failure of the Service Water Reservoir impounding dike would not inundate the plant site.

The NRC staff confirmed the licensee's conclusion that the reevaluated hazard from flooding from dam failures on the North Anna River is not bounded by the CDB flood hazard. Therefore, the NRC staff anticipates that the licensee will submit a focused evaluation confirming the capability of flood protection and available physical margin or a revised integrated assessment consistent with COMSECY-15-0019 (NRC, 2015b).

3.5 Storm Surge

The FHRR reported that the reevaluated hazard, including associated effects, for storm surge does not inundate the plant site, and thus did not report a flooding elevation.

This flood-causing mechanism is discussed in the licensee's CDB, where the licensee stated that surge flooding would not inundate the plant site because the site is not located on an estuary or open coast (Dominion, 2011, Section 2.4.5).

Section 2.4 of the FHRR stated that the site is free from the potential surge flooding from estuary or ocean because the site is located far from any ocean. The FHRR also considered potential surge flooding from the Lake Anna as follows: With a 100-year flood scenario, the FHRR estimated a stillwater flood elevation in the lake of approximately 255 ft (77.7 m) NGVD29 from a flood insurance study by the Federal Emergency Management Agency (FEMA, 1997). The FHRR (Section 2.2.6) calculated maximum wind setup as 0.09 ft (0.03 m), and maximum wave runup as 3.03 ft (0.924 m). These values, added to the stillwater elevation of 255 ft (77.7 m), gave a flood elevation of 258 ft (78.6 m). This flood level was 13 ft (4.0 m) below the plant grade of 271.0 ft (82.60 m). Therefore the licensee concluded that the lake surge level with wind effects will not inundate the plant site.

The NRC staff reviewed the onsite surge flooding during the review of the Unit 3 Early Site Permit application (Dominion, 2006). As a result, the NRC staff concluded that the site is not subject to ocean storm surge because the site is located 50 mi (80 km) inland from the nearest body of ocean water (i.e., the Chesapeake Bay) and is sited more than 270 ft (82.3 m) above mean sea level.

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

3.6 Seiche

The FHRR (Section 2.5) reported that the reevaluated hazard, including associated effects, for seiche does not inundate the plant site, thus did not report a probable maximum flood elevation. This flood-causing mechanism is discussed in the licensee's CDB, but no impact was identified.

The FHRR stated that seiche-induced lake flooding is not expected to affect the safety-related facilities of NAPS, Units 1 and 2 for the following reasons:

- No historical occurrence of any seiches on Lake Anna has been reported in any literature or by plant personnel.
- Some seiche generating mechanisms, such as tides and landslides, can be precluded due to the physical, hydrological, geological, and topographical conditions of Lake Anna and the region.

- Atmospheric and seismic events have characteristic periods significantly different from the natural oscillation period of the lake, which would range from 9.5 min to 11.5 min. Thus, in-phase amplification of the seiche motion within the lake is not likely.

For the same reasons, the NRC staff concluded during the review of the NAPS, Unit 3 Early Site Permit application (Dominion, 2006) that seiche is not expected to impact the plant and its operation.

The NRC staff confirmed the licensee's conclusion that the reevaluated hazard for flooding from seiche is bounded by the CDB flood hazard.

3.7 Tsunami

The FHRR reported that reevaluated hazard, including associated effects, for tsunami does not inundate the plant site, thus did not report a probable maximum flood elevation. This flood-causing mechanism is described in the licensee's CDB, where no impact was identified.

The NRC staff confirmed this conclusion. The NRC staff also concluded during its review of the Early Site Permit application (NRC, 2005) that the site would remain dry even under conservative assumptions if a lake tsunami were generated by a severe landslide into the lake.

The NRC staff confirmed the licensee's conclusion that the reevaluated hazard for flooding from tsunami is bounded by the CDB flood hazard.

3.8 Ice-Induced Flooding

The FHRR reported that the reevaluated hazard, including associated effects, for ice-induced flooding does not inundate the plant site. Therefore, the licensee did not report a PMF elevation. This flood-causing mechanism is discussed in the licensee's CDB, but no impact was identified (Dominion, 2011, Section 2.4.7).

The FHRR estimated, using conservative assumptions, that failure of an upstream ice dam could raise the level of Lake Anna by 0.4 ft (0.1 m). The FHRR concluded that there was no discernable risk of flooding from downstream ice dams, because the North Anna River downstream from the dam is about 85 ft (26 m) lower than the dam crest elevation.

For the reevaluation, the licensee analyzed flooding caused by ice jams upstream or downstream of the site and ice that blocks the drainage system, as summarized below:

- The licensee reviewed air temperature records at Richmond International Airport extending from 1939 to 2012, and found several periods of consecutive below freezing days. These records indicate potential cold weather periods conducive to ice jam formation in the region.

- Querying the USACE's Ice Jam Database (USACE, 2012), the licensee identified 19 records of ice jam events in the vicinity of the plant site. Two of these records are notable: (1) The ice jam on February 11, 1936 on the James River produced high water levels and breakups with releasing ice and water downstream; and (2) The ice jam, 4 ft (1.2 m) to 6 ft (1.8 m) thick, on December 30, 1998 on the Rappahannock River produced high water levels but minimal flooding. Therefore, the licensee determined that there is a potential for ice jam formation in the area.

- The licensee postulated a potential ice formed impoundment scenario upstream from the site. The licensee assumed the ice impoundment was 10 ft (3.0 m) in height and 1500 acre-ft (1,900,000 m^3) in volume conservatively. The height is based on the historical maximum ice thickness of 4 ft (1.2 m) to 6 ft (1.8 m), and the volume is based on the topography data for an area of 150 acre (610,000 m^2) and a water depth of 10 ft (3.0 m) conservatively. The licensee stated that this ice flooding scenario is bounded by the failure scenario of two upstream dams discussed in the dam failure flood reevaluation in the FHRR.

- The licensee mentioned that an ice jam downstream of the Lake Anna would not affect the site flooding because the difference in elevations between the plant grade and the bottom of the downstream river is about 180 ft (55 m).

- Therefore, the licensee determined that there is no risk of flooding at the site due to ice jam formed upstream or downstream of the site.

During its review (NRC, 2005) of the NAPS, Unit 3 Early Site Permit application (Dominion, 2006), the NRC staff determined that any flood produced by breakage of the largest ice dams in North Anna River would not flood the plant site. During its review of the FHRR, the NRC staff identified one ice jam over the past 70 years from the USACE's Ice Jam Database (USACE, 2012) on the North Anna River. The NRC staff noted that ice sheets have been formed only on the upper reaches of Lake Anna. However, the NRC staff found that none of these events would create river ice jam flooding that exceeds the licensee-postulated ice-induced impoundment scenario. Therefore the NRC staff determined that ice-jam flooding in the river would not inundate the plant site.

The NRC staff confirmed the licensee's conclusion that the reevaluated hazard for ice-induced flooding of the site is bounded by the CDB flood hazard.

3.9 Channel Migrations or Diversions

The FHRR reported that the reevaluated hazard, including associated effects, for channel migrations or diversions does not inundate the plant site, but did not report a PMF elevation. This flood-causing mechanism is discussed in the licensee's CDB, but no PMF elevation was reported (Dominion, 2011).

The FHRR (Section 2.8) concluded that the potential of upstream diversion flooding is considered extremely remote because (1) the North Anna River course has not been changed in recent history, (2) the river has a 250 ft (76 m) deep valley from the surrounding drainage divide, making it difficult to erode entirely, and (3) there is no apparent man-made or natural event that could divert the North Anna River.

For the same reasons, the NRC staff found during its review of the Unit 3 Early Site Permit that flooding caused by channel diversion above Lake Anna is not likely (NRC, 2005). The NRC staff did not find any information during its review of the FHRR that indicated that channel diversion has since become more likely.

The NRC staff confirmed the licensee's conclusion that the reevaluated hazard for flooding from channel migrations or diversions is bounded by the CDB flood hazard.

4.0 UNBOUNDED HAZARDS AND ASSOCIATED HAZARD DATA

The NRC staff confirmed that the reevaluated flood hazard results for LIP, rivers and streams, and dam failure flood-causing mechanism are not bounded by the North Anna Power Station, Units 1 and 2 CDB hazard. Therefore, the NRC staff anticipates that the licensee will perform additional assessments (focused evaluation or revised Integrated Assessment) of plant response.

Consistent with COMSECY-15-0019 (NRC, 2015b), the NRC staff expects the licensee will submit a focused evaluation for LIP and associated site drainage.

For the rivers and streams and dam failure flood-causing mechanisms, the NRC staff anticipates that the licensee will submit a focused evaluation confirming the capability of flood protection and available physical margin or a revised integrated assessment.

The NRC staff reviewed the following flood hazard parameters needed to perform the additional assessments of plant response:

- 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. Reevaluated flood height and associated effects for the flood-causing mechanisms identified above are shown in Table 4.0-2 and Table 4.0-3.

Wind effect associated with Lake Anna flooding is discussed in Sections 3.3 and 3.4. The licensee incorporated wind effects on river PMF in Lake Anna and debris effects implicitly on the LIP flood analyses. However, the licensee did not evaluate wind effects on dam failure flooding in Lake Anna because the reevaluated flood elevation from upstream dam failures does not inundate the plant site. The NRC staff found this to be an appropriate response. The NRC staff also concluded that other associated effects, including the effects of hydrodynamic loading, erosion and sedimentation, and groundwater ingress are not applicable to this site, and therefore, do not need to be evaluated.

The NRC staff requested, via an RAI (NRC, 2013b), the licensee to provide additional information to supplement the FHRR as discussed in Section 3.0 of this staff assessment. This RAI requested the applicable flood event duration parameters. The licensee's response (Dominion, 2013c) to this RAI is summarized as follows:

- The LIP-induced flood caused by a 6-hour PMP event results in the highest water surface elevation at the Protected Area. Per this flooding mechanism, the maximum flood elevation is 274.5 ft (83.67 m) NGVD29, with the following flood duration parameters:
    - Flooding warning time of "up to 36 hours or greater"
    - Flood inundation duration of 32 min for a 6-hr onsite PMP event
    - Flood recession time of 32 min for a 6-hr onsite PMP event

- For the postulated LIP event, the licensee begins to implement mitigation actions in accordance with the NAPS Procedure 0-AP-41 (Severe Weather Conditions) when (1) hurricane force winds are projected, (2) a high wind warning projects wind speed greater than 35 mi/h (56 km/h), (3) a severe thunderstorm watch or warning is issued for the area, or (4) a predicted total rainfall exceeds 12 in (30 cm) for a duration up to 72 hour for the site.

- For the LIP event, the flood elevations above the plant grade range from 0.3 ft (0.09 m) to 2.9 ft (0.88 m) at the Protected Area.

The NRC staff expects that the licensee will assess available warning time associated with LIP as part of the additional assessment of plant response consistent with the focused evaluation.

Based upon the preceding analysis, NRC staff confirmed that the reevaluated flood hazard information defined in the sections above is appropriate input to the additional assessments of plant response as described in the 50.54(f) letter and COMSECY-15-0019 (NRC, 2015b).

5.0 CONCLUSION

The NRC staff has reviewed the information provided for the reevaluated flood-causing mechanisms for NAPS, Units 1 and 2. Based on its review, 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 (a) the reevaluated flood hazard results for LIP, streams and river flooding, and upstream dam failure flooding are not bounded by the CDB flood hazard, (b) additional assessments of plant response will be performed for the LIP, rivers and streams and dam failure flood-causing mechanisms, and (c) 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, 2015b).

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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

Note: SRP is the Standard Review Plan (NRC, 2007)

Note: JLD-ISG-2013-01 is "Guidance For Assessment of Flooding Hazards Due to Dam Failure," (NRC, 2013a)

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

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

Reevaluated Flood-Causing Mechanisms and Associated Effects that May Exceed the Powerblock Elevation (271 ft (82.6 m) NGVD29)[1,2]		**ELEVATION ft (m) NGVD29**
LIP and Associated Drainage	Protected Area outside the West Basin	274.5 (83.7)

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

[2] The plant grade at the Powerblock is 271.0 ft (82.60 m) NGVD29.

Table 3.1-2. Current Design Basis Flood Hazards

Flooding Mechanism		Design Basis Stillwater Level ft (m) NGVD29	Design Basis Associated Effects ft (m)	Current Design Basis Flood Level ft (m) NGVD29	Reference
LIP and Associated Drainage	Protected Area	Ground level with no accumulation	Not Applicable	Ground level with no accumulation (Grade level is 271.0 (82.60))	FHRR Section 1.2 and Table 3.0-1
	West Basin	256.1 (78.06)	Not Applicable	256.1(78.06)	FHRR Section 1.2 and Table 3.0-1
Streams and Rivers/ Lake Anna		264.2 (80.53)	3.1 (0.94) (backwater and wind effects)	267.3 (81.47)	FHRR Section 1.2 and Table 3.0-1
Failure of Dams and Onsite Water Control/Storage Structures (Lake Anna)		No impact identified	No impact identified	No impact identified	FHRR Section 1.2 and Table 3.0-1
Storm Surge		No impact identified	No impact identified	No impact identified	FHRR Section 1.2 and Table 3.0-1
Seiche		No impact identified	No impact identified	No impact identified	FHRR Section 1.2 and Table 3.0-1
Tsunami		No impact identified	No impact identified	No impact identified	FHRR Section 1.2 and Table 3.0-1
Ice-Induced		No impact identified	No impact identified	No impact identified	FHRR Section 1.2 and Table 3.0-1
Channel Migrations or Diversions		No impact identified	No impact identified	No impact identified	FHRR Section 1.2 and Table 3.0-1

Table 3.4-1. Factors of Safety Associated with Seismic Slope Stability Evaluation Using Seed Method

k_h Pseudostatic Coefficient	k_y Yield Coefficient	Factor of Safety (Undrained)	
		Downstream Slope	Upstream Slope
0.15	-0.08	1.528	1.323
0.15	0.08	1.569	1.515

Source: Dominion, 2015

Table 3.4-2. Liquefaction Analysis Results Using Best Estimate Shear Wave Velocity Profile and Shear-Wave Velocity-Based Correlations

Moment Magnitude: 7.10; Peak Ground Acceleration (PGA) (g): 0.28; Depth of Groundwater Table (ft): 0.0; Magnitude Scaling Factor (MSF): 1.174

MEASURED SHEAR WAVE VELOCITY			STRATIGRAPHY INFORMATION		OVERBURDEN STRESS			CORRECTED SHEAR WAVE VELOCITY			CYCLIC RESISTANCE RATIO			CYCLIC STRESS RATIO		FACTOR OF SAFETY (Age Factor = 2)	FACTOR OF SAFETY (Age Factor = 1)
Elevation	Depth	Shear Wave Velocity, V_s	Fines Content	Unit Weight	u	σ_{vo}	σ_{vo}'	V_s	V_{s1}	V_{s1}^*	$CRR_{7.5}$	K_σ (D_r=60%)	CRR	r_d	CSR		
(ft)	(ft)	(ft/sec)	(%)	(pcf)	(psf)			(m/sec)									
317.5	2.50	472.0	29	125.0	156.0	312.5	158.5	143.9	275.9	200.0	2.00	1.00	2.35	0.99	0.36	13.0	6.5
312.5	7.50	690.0	29	125.0	468.0	937.5	469.5	210.3	306.4	200.0	2.00	1.00	2.35	0.98	0.36	13.2	6.6
307.5	12.50	755.0	29	125.0	780.0	1562.5	782.5	230.1	295.1	200.0	2.00	1.00	2.35	0.97	0.35	13.3	6.7
302.5	17.50	787.0	29	125.0	1092.0	2187.5	1095.5	239.9	282.8	200.0	2.00	1.00	2.36	0.96	0.35	13.5	6.7
297.5	22.50	814.0	29	125.0	1404.0	2812.5	1408.5	248.1	274.7	200.0	2.00	1.00	2.35	0.95	0.34	13.6	6.8
292.5	27.50	838.0	29	125.0	1716.0	3437.5	1721.5	255.4	268.9	200.0	2.00	1.00	2.35	0.94	0.34	13.8	6.9
287.5	32.50	860.0	29	125.0	2028.0	4062.5	2034.5	262.1	264.7	200.0	2.00	1.00	2.35	0.91	0.33	14.2	7.1
282.5	37.50	880.0	29	125.0	2340.0	4687.5	2347.5	268.2	261.4	200.0	2.00	0.97	2.28	0.87	0.32	14.4	7.2
277.5	42.50	898.0	29	125.0	2652.0	5312.5	2660.5	273.7	258.5	200.0	2.00	0.93	2.19	0.83	0.30	14.6	7.3
272.5	47.50	915.0	29	125.0	2964.0	5937.5	2973.5	278.9	256.2	200.0	2.00	0.90	2.12	0.79	0.29	14.8	7.4
267.5	52.50	931.0	29	125.0	3276.0	6562.5	3286.5	283.8	254.2	200.0	2.00	0.88	2.06	0.75	0.27	15.2	7.6
262.5	57.50	946.0	29	125.0	3588.0	7187.5	3599.5	288.3	252.6	200.0	2.00	0.85	2.00	0.71	0.26	15.6	7.8
257.5	62.50	960.0	29	125.0	3900.0	7812.5	3912.5	292.6	250.9	200.0	2.00	0.83	1.95	0.67	0.24	16.2	8.1
252.5	67.50	973.0	29	125.0	4212.0	8437.5	4225.5	296.6	249.5	200.0	2.00	0.81	1.91	0.62	0.23	16.8	8.4
247.5	72.50	986.0	29	125.0	4524.0	9062.5	4538.5	300.5	248.3	200.0	2.00	0.80	1.87	0.58	0.21	17.6	8.8
242.5	77.50	998.0	29	125.0	4836.0	9687.5	4851.5	304.2	247.2	200.0	2.00	0.78	1.83	0.56	0.20	18.0	9.0
237.5	82.50	1009.0	29	125.0	5148.0	10312.5	5164.5	307.5	246.1	200.0	2.00	0.77	1.80	0.56	0.20	17.7	8.8

Table 4.0-1. Flood Event Duration for Reevaluated Flood-Causing Mechanisms Not Bounded by the Plant's CDB

Flood-Causing Mechanism		Site Preparation for Flood Event	Period of Site Inundation	Recession of Water from Site
LIP and Associated Drainage	Protected Area Outside the West Basin	"from 2.5 hours and up to 36 hours or greater"	32 min	32 min
	West Basin	Not Provided	Not Provided	Not Provided
Stream and River Flooding		Not applicable		
Dam Failure (Lake Anna)		Not applicable		

Source: Response to RAI (Dominion, 2013c)

Note: LIP scenario is based on a 6-h, 1-mi^2 (2.6-km^2) PMP event. Staff expects that the licensee will assess available warning time associated with LIP as part of additional assessment of plant response consistent with the described in the NEI White Paper, "Warning Time for Maximum Precipitation Events," dated April 8, 2015 (ADAMS Accession No. ML15104A157), and the related NRC letter dated April 23, 2015 (ADAMS Accession No. ML15110A080).

Note: Stream and river PMF scenario is based on a combined event of the 40-percent PMP plus the full 72-h PMP event.

Note: The licensee is expected to develop flood event duration parameters to conduct the Mitigating Strategies Assessment (MSA) as discussed in the latest revision to NEI-12-06, Appendix G (See ComSecy-15-0019). The staff will evaluate the flood event duration parameters during its review of the MSA.

Table 4.0-2. Reevaluated Flood Hazards for Flood-Causing Mechanisms Not Bounded by the Plant's CDB

Reevaluated Flood-Causing Mechanism		Stillwater Elevation, ft (m) NGVD29	Flood Event Duration, ft (m)	Reevaluated Flood Hazard, ft (m) NGVD29[1]	Reference
LIP and Associated Drainage	Protected Area outside West Basin	274.5 (83.67)	Wind effects are minimal. Debris affects are considered implicitly on the staff stillwater elevation estimate	274.5 (83.67)	FHRR Section 2.1
	West Basin	>257.0(>78.33)[3]	Wind effects are minimal. Debris affects are considered implicitly on the staff stillwater elevation estimate	>257.0 (>78.33)[3]	FHRR Sections 2.1.2 and 3.0
Stream and River Flooding		264.1 (80.5)	3.32 (1.0) for wind effects	267.4 (81.5)[2]	FHRR Section 2.2
Dam Failure (Lake Anna)		264.7 (80.7)	Not Applicable[4]	264.7 (80.7)	FHRR Section 2.3

[1] The plant grade at the Powerblock is 271.0 ft (82.60 m) NGVD29.

[2] Adding the wind setup and wave run-up values to the PMF still water elevation resulted in a maximum PMF elevation at Units 1 and 2 of 267.42 ft (81.510 m) NGVD29 (i.e., 264.1 ft (80.50 m) NGVD29 stillwater PMF level at the dam + 0.2 ft (0.06 m) backwater to the station + 0.09 ft (0.03 m) wind setup + 3.03 ft (0.924 m) wave runup).

[3] The FHRR (p. 3.0-1) stated that the reevaluated flood elevation inside the Turbine Building as a result of flooding in the West Basin is above the elevation of the Turbine Building flood protection wall. This flooding issue needs to be addressed in the focused evaluation.

[4] The FHRR (Section 2.3.2) noted that additional refinement of dam failure flood analysis including associated effects is not necessary due to the sufficient margin indicated by the licensee's initial conservative analysis.

Note: The licensee is expected to develop flood event duration parameters to conduct the Mitigating Strategies Assessment (MSA) as discussed in the latest revision to NEI-12-06, Appendix G (See ComSecy-15-0019). The staff will evaluate the flood event duration parameters during its review of the MSA.

Table 4.0-3 Associated Effects Inputs for Mechanisms Not Bounded by the Plant's CDB

	Flooding Mechanism			
Associated Effects Factor	LIP and Associated Drainages		River Flooding on Lake Anna	Dam Failure (Lake Anna)
	Protected Area Outside the West Basin	West Basin		
Wind waves and runup	Not applicable	Not applicable	0.09 ft (0.03 m)	Not applicable[2]
Wind setup	Not applicable	Not applicable	3.03 ft (0.924 m)	Not applicable[2]
Backwater	Not applicable	Not applicable	0.2 ft (0.06 m)	Not applicable[2]
Hydrodynamic loading at plant grade	Not applicable	Not applicable	Not applicable[2]	Not applicable[2]
Debris loading at plant grade	Minimal	Minimal	Not applicable[2]	Not applicable[2]
Sediment loading at plant grade	Minimal	Minimal	Not applicable[2]	Not applicable[2]
Sediment deposition and erosion	Minimal	Minimal	Not applicable[2]	Not applicable[2]
Concurrent conditions, including adverse weather	Minimal	Minimal	Not applicable[2]	Not applicable[2]
Groundwater ingress	Minimal	Minimal	Not applicable[2]	Not applicable[2]
Other pertinent factors (e.g., waterborne projectiles)	Minimal	Minimal	Not applicable[2]	Not applicable[2]

[1] The FHRR (Section 2.1) stated that underground storm drains and culverts, as well as roof drains, are assumed to be clogged and not functioning due to debris and sediment effects during the LIP storm event.

[2] Associated Effects are not necessary due to the sufficient margin indicated by the initial conservative analysis (FHRR, Section 2.3.2).

Figure 2.2-1: Flood Event Duration

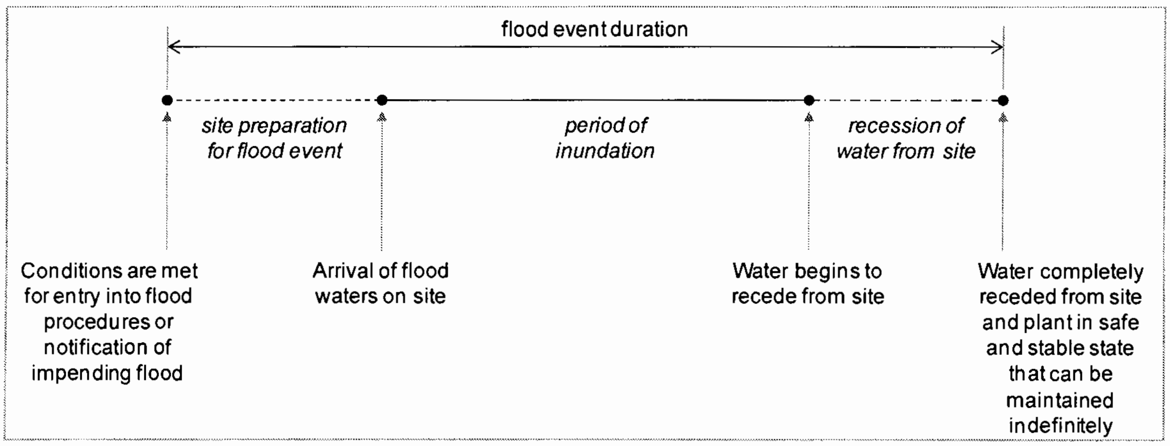
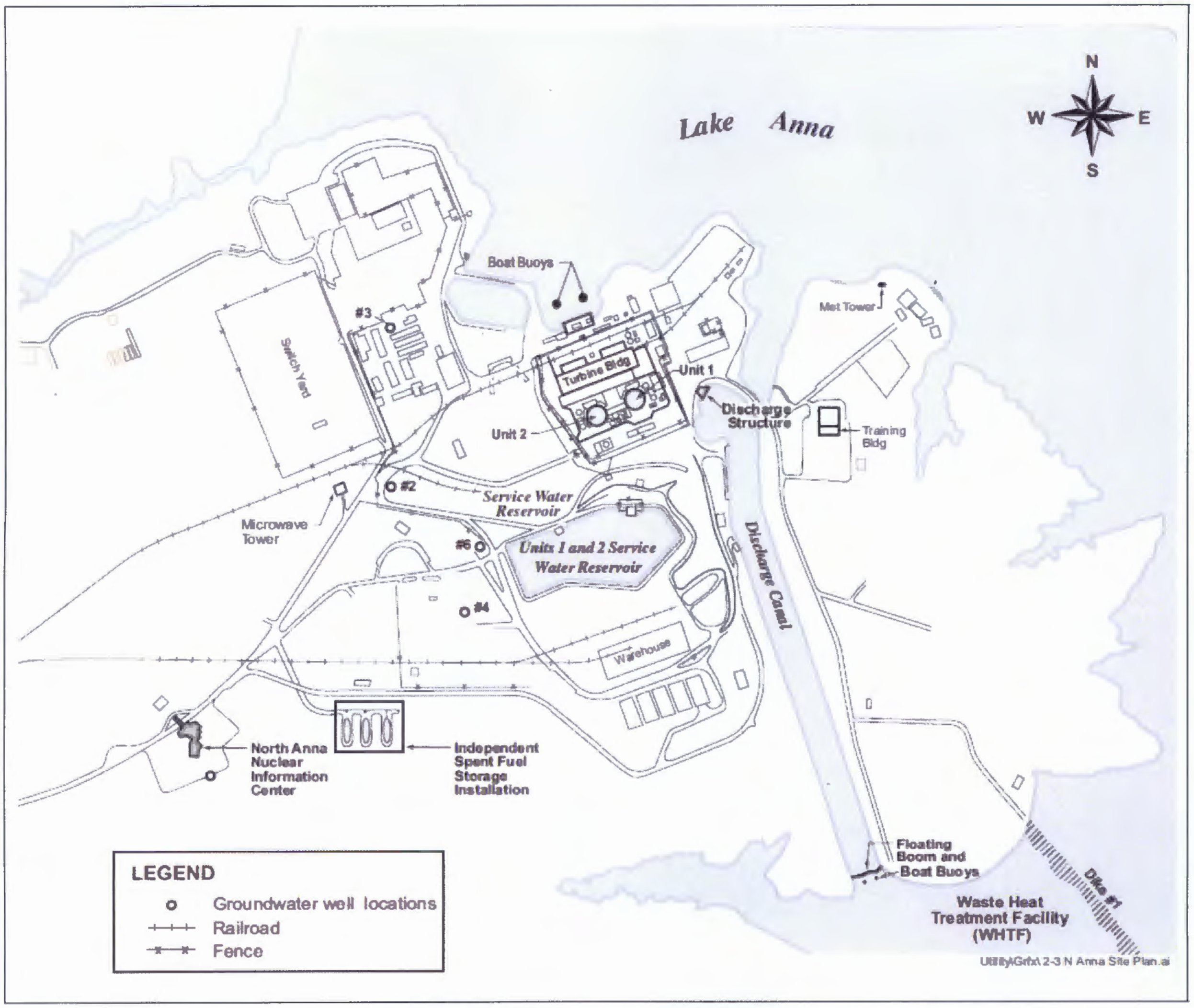
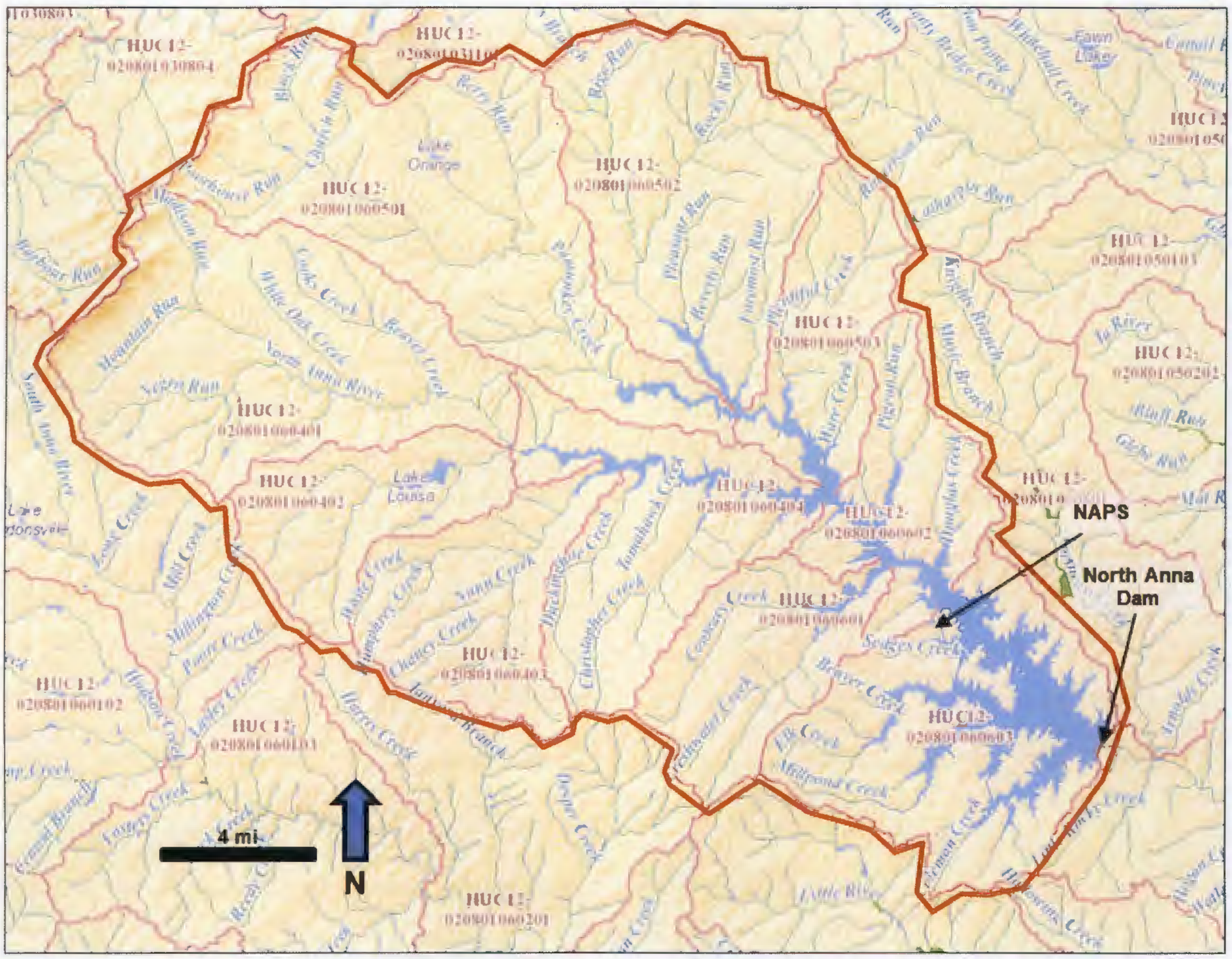


Figure 3.1-1. Site Layout of North Anna Power Station



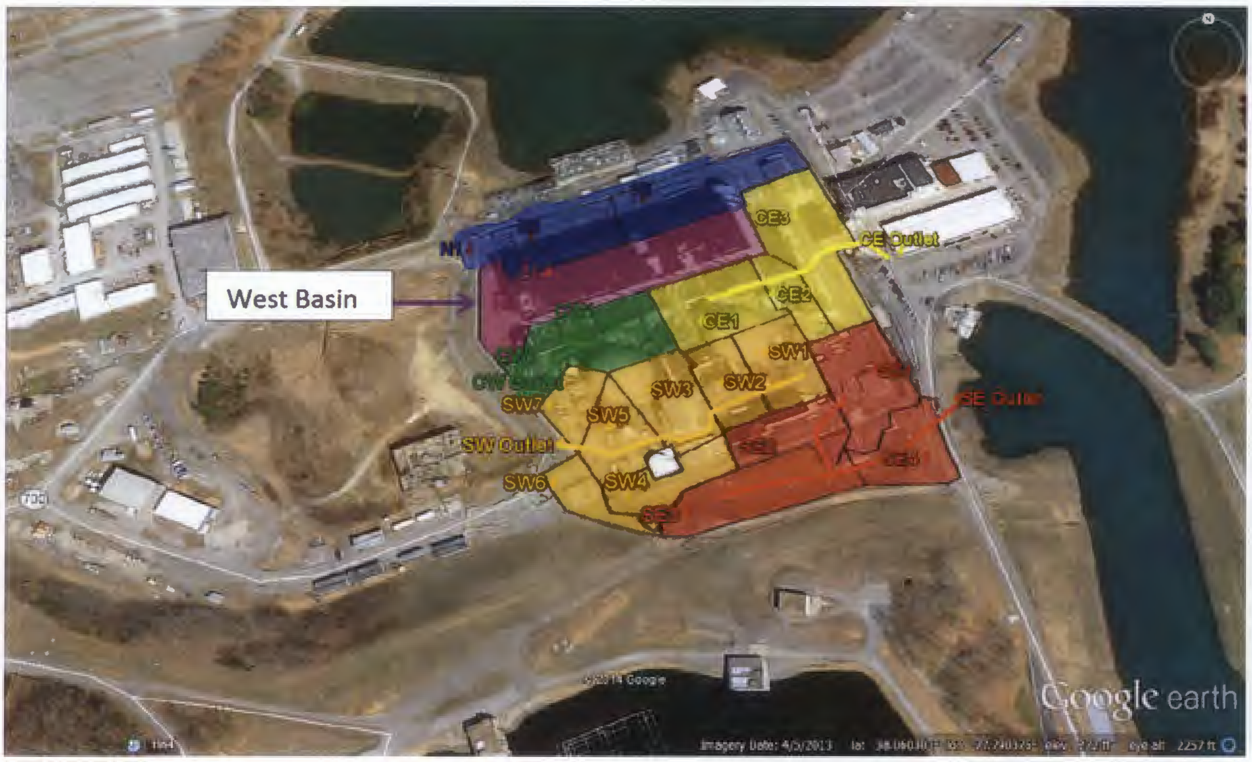
Source: Early Site Permit Site Safety Analysis Report (Dominion, 2006, Figure 1.2-3)

Figure 3.1-2. North Anna River Watershed



Source: Base from U.S. Geological Survey, National Map Viewer (USGS, 2015). Watershed boundary by NRC staff.

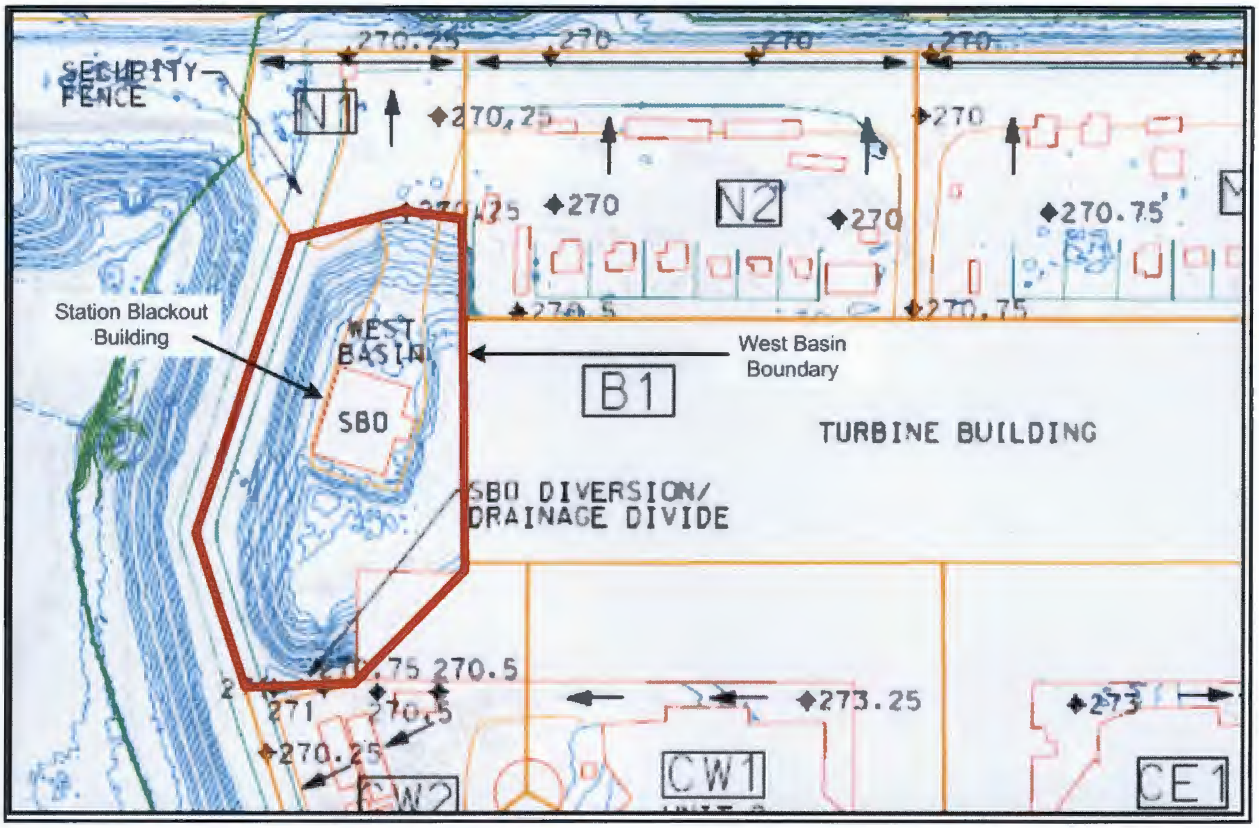
Figure 3.1-3. HEC-HMS Drainage Subbasin Model and HEC-RAS Flowpaths for Protected Area, Including the West Basin



Source: Prepared by the staff, based on information from FHRR Figure 2.1-1.

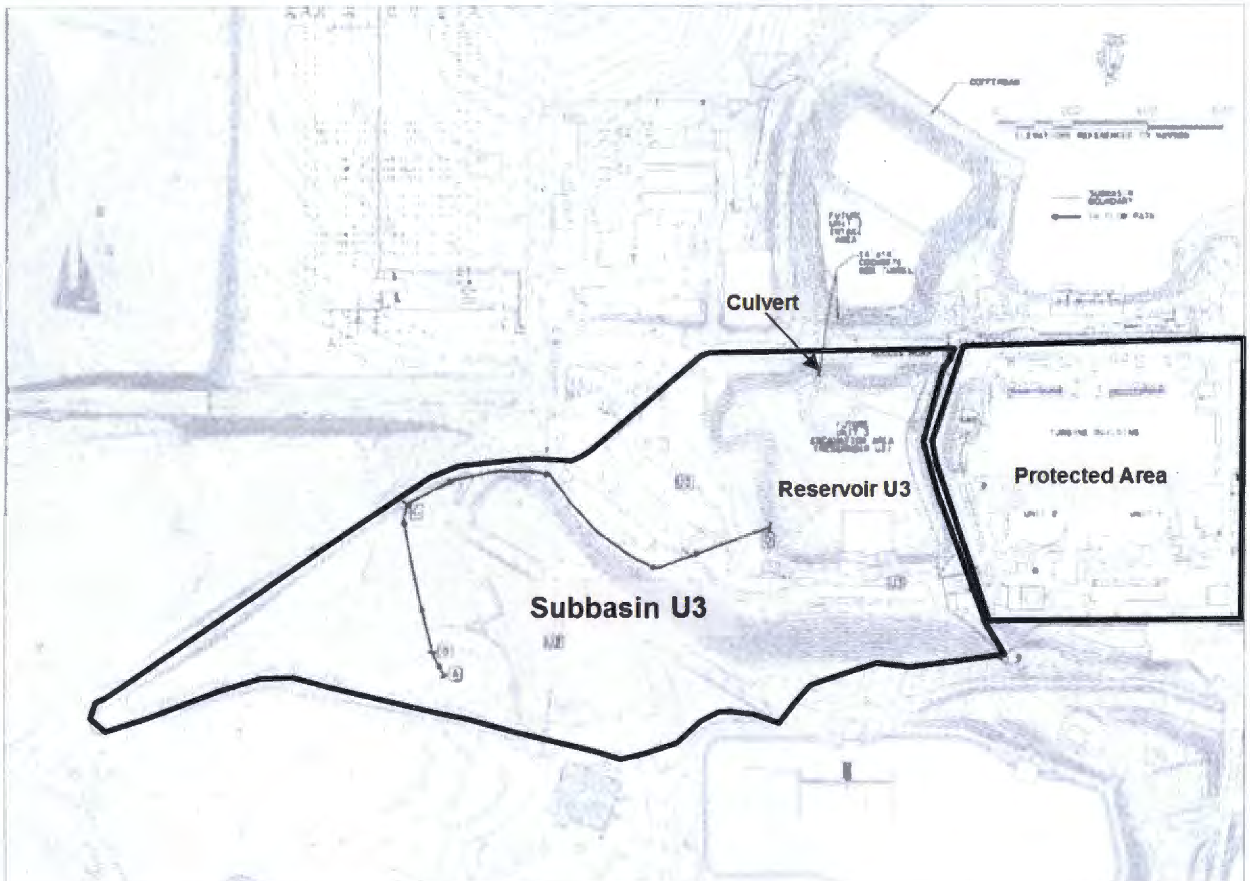
Note: Central west subbasins are shown in green. North subbasins, including Turbine Building and West Basin, are shown in magenta.

Figure 3.1-4. HEC-HMS Model Boundary for the West Basin



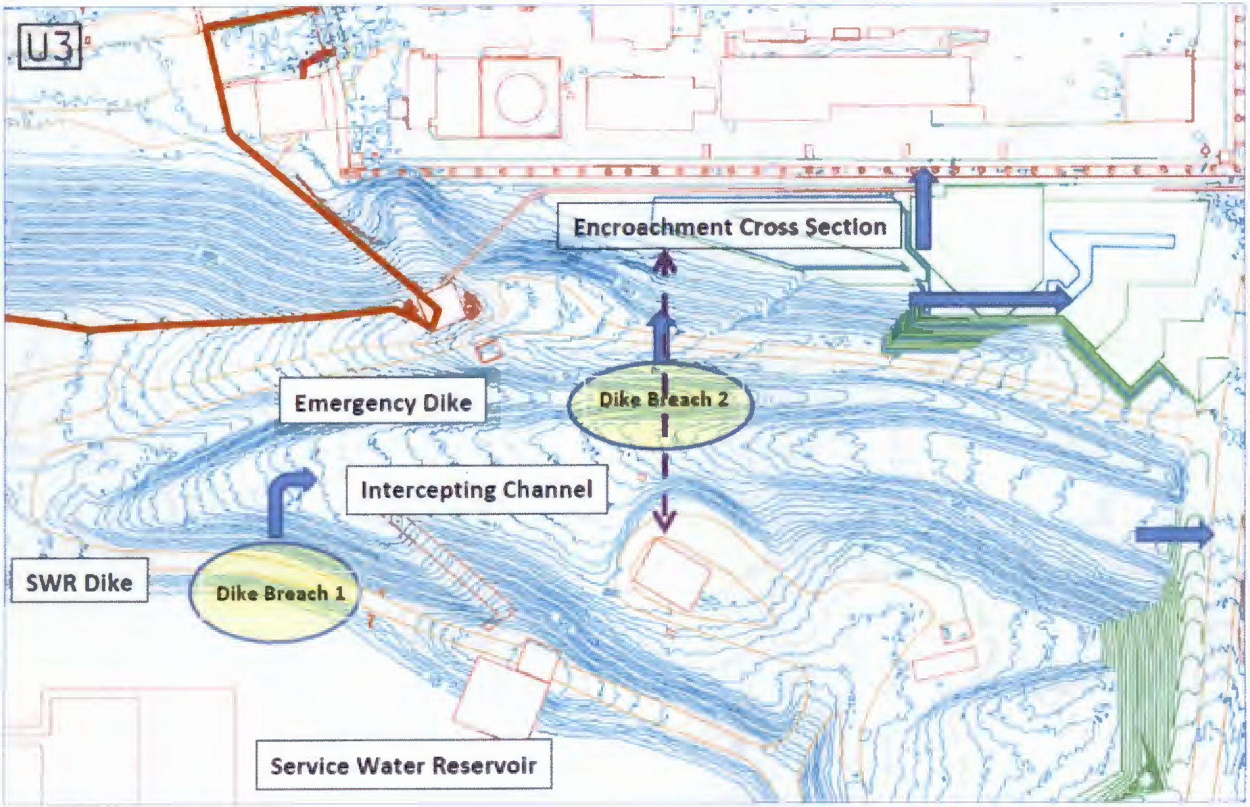
Source: Modified from FHRR Figure 2.1-1.

Figure 3.2-1. Area West of Plant, Including Subbasin U3



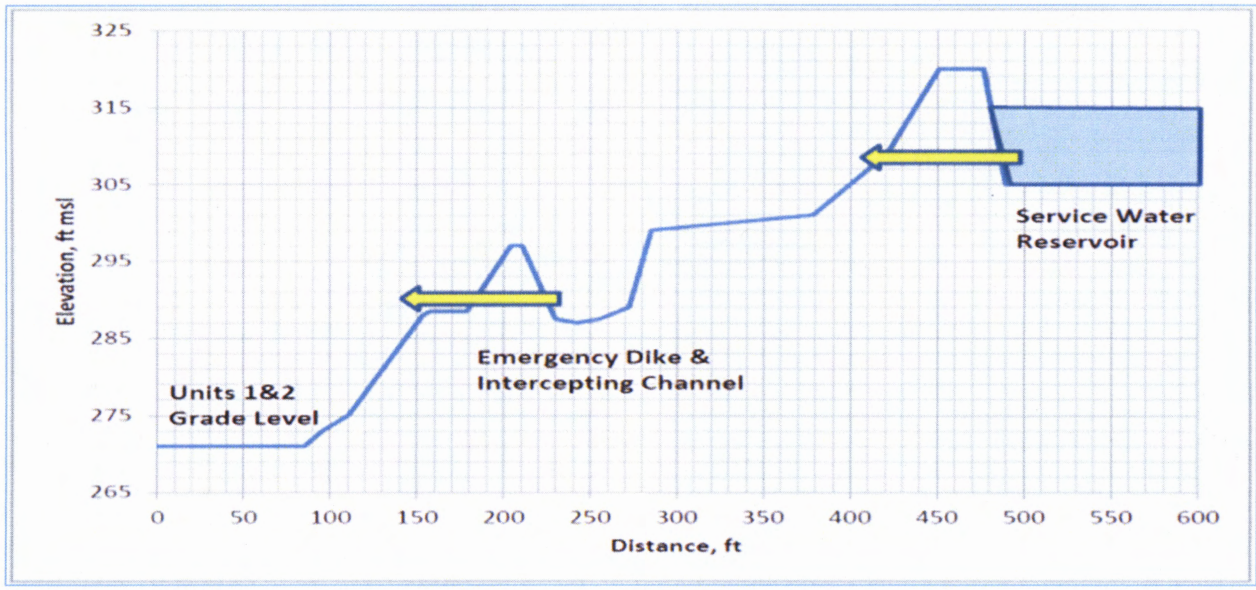
Source: Modified from FHRR Figure 2.1-2

Figure 3.4-1. Location of Postulated Dike Breaches on the Service Water Reservoir and Emergency Dike (Top), and Cross Section Profile (Bottom)



Source: Top part modified from RAI response (Dominion, 2013c, Map 3 of 4), while bottom part prepared by the staff.

Note: "SWR Dike" is the Service Water Reservoir Impounding Dike.


325
315
305
295
285
275
265
Elevation, ft msl
0
50
100
150
200
250
300
350
400
450
500
550
600
Distance, ft
Units 1&2
Grade Level
Emergency Dike &
Intercepting Channel
Service Water
Reservoir

Nuclear Energy Institute (NEI) 12-06 "Diverse and Flexible Coping Strategies (FLEX) Implementation Guide," is currently being revised. This revision will include a methodology to perform an MSA with respect to the reevaluated flood hazards. Once this methodology is endorsed by the NRC, flood event duration parameters and applicable flood associated effects should be considered as part of the North Anna MSA. The NRC staff will evaluate the flood event duration parameters (including warning time and period of inundation) developed by the licensee during the NRC staff's review of the MSA.

The reevaluated flood hazard results for local intense precipitation, rivers and streams, and dam failure flood-causing mechanisms were not bounded by respective current plant design-basis hazards. In order to complete its response to the information requested by Enclosure 2 to the 50.54(f) letter, the licensee is expected to submit an integrated assessment or a focused evaluation, as appropriate, to address these reevaluated flood hazards, as described in NRC letter, "Coordination of Requests for Information Regarding Flooding Hazard Reevaluations and Mitigating Strategies for Beyond-Design-Basis External Events," (ADAMS Accession No. ML15174A257). This letter describes the changes in the NRC's approach to the flood hazard reevaluations that were approved by the Commission in its Staff Requirements Memorandum to COMSECY-15-0019 "Mitigating Strategies and Flooding Hazard Reevaluation Action Plan," (ADAMS Accession No. ML15153A104).

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. 50-338 and 50-339

Enclosure:
Staff Assessment of Flood Hazard
Reevaluation Report

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