UNITED STATES
NUCLEAR REGULATORY COMMISSION
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December 21, 2016

Mr. David A. Heacock
President and Chief Nuclear Officer
Virginia Electric and Power Company
5000 Dominion Blvd.
Glen Allen, VA 23060-6711

SUBJECT: SURRY POWER STATION, UNIT NOS. 1 AND 2 – STAFF ASSESSMENT OF RESPONSE TO 10 CFR 50.54(f) INFORMATION REQUEST – FLOOD-CAUSING MECHANISM REEVALUATION (CAC NOS. MF6102 AND MF6103)

Dear Mr. Heacock:

By letter dated March 12, 2012, the U.S. Nuclear Regulatory Commission (NRC) issued a request for information pursuant to Title 10 of the *Code of Federal Regulations*, Section 50.54(f) (hereafter referred to as the 50.54(f) letter). The request was issued as part of implementing lessons learned from the accident at the Fukushima Dai-ichi nuclear power plant. Enclosure 2 to the 50.54(f) letter requested that licensees reevaluate flood-causing mechanisms using present-day methodologies and guidance. By letter dated March 12, 2015 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML15078A291), Virginia Electric and Power Company (Dominion, the licensee) responded to this request for Surry Power Station, Unit Nos. 1 and 2 (Surry).

By letter dated February 29, 2016 (ADAMS Accession No. ML16041A341), the NRC staff sent the licensee a summary of the staff's review of Surry's reevaluated flood-causing mechanisms. The enclosed staff assessment provides the documentation supporting the NRC staff's conclusions summarized in the letter. As stated in the letter, the reevaluated flood hazard results for local intense precipitation (LIP) and associated drainage, failure of dams and onsite water control/storage structures, and storm surge were not bounded by the current design-basis flood hazard. In order to complete its response to Enclosure 2 to the 50.54(f) letter, the licensee is expected to submit a focused evaluation for LIP and additional assessments for the other effects specified in the letter to address this reevaluated flood hazard, as described in an NRC letter issued September 1, 2015 (ADAMS Accession No. ML15174A257). This closes out the NRC's efforts associated with CAC Nos. MF6102 AND MF6103.

Enclosure 1 transmitted herewith contains security-related information. When separated from Enclosure 1, this document is decontrolled.

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

Sincerely,

Lauren Kati Gibson

Lauren K. Gibson, Project Manager
Hazards Management Branch
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Docket Nos. 50-280 and 50-281

Enclosures:
1. Staff Assessment of Flood Hazard Reevaluation Report (non-public, security-related information)
2. Staff Assessment of Flood Hazard Reevaluation Report (public)

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STAFF ASSESSMENT BY THE OFFICE OF NUCLEAR REACTOR REGULATION RELATED TO FLOODING HAZARD REEVALUATION REPORT NEAR-TERM TASK FORCE RECOMMENDATION 2.1 SURRY POWER STATION, UNIT NOS. 1 AND 2 DOCKET NOS. 50-280 AND 50-281

1.0 INTRODUCTION

By letter dated March 12, 2012 (NRC, 2012a), the U.S. Nuclear Regulatory Commission (NRC) issued a request for information to all power reactor licensees and holders of construction permits in active or deferred status, pursuant to Title 10 of the *Code of Federal Regulations* (10 CFR), Section 50.54(f), "Conditions of Licenses" (hereafter referred to as the "50.54(f) letter"). The 50.54(f) was issued in connection with the implementation of the lessons-learned from the 2011 accident at the Fukushima Dai-ichi nuclear power plant, as documented in the NRC's Near-Term Task Force Report (NRC, 2011b). Recommendation 2.1 in that document recommended that the staff issue orders to all licensees to reevaluate seismic and flooding hazards for their sites using current NRC requirements and guidance. Subsequent staff requirements memoranda associated with SECY-11-0124 (NRC, 2011c) and SECY-11-0137 (NRC, 2011d) directed the NRC staff to issue requests for information to licensees pursuant to 10 CFR 50.54(f).

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

If the reevaluated hazard for any flood-causing mechanism 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 COMSECY-15-0019, "Mitigating Strategies and Flooding Hazard Reevaluation Action Plan" (NRC, 2015a).

Additionally, for any reevaluated flood hazards that are not bounded by the plant's CDB hazard, the licensee is expected to develop flood event duration (FED) parameters and associated effects (AE) to conduct the mitigating strategies assessment (MSA) and focused evaluations or revised integrated assessments.

By letter dated March 12, 2015 (Dominion, 2015), Virginia Electric and Power Company (Dominion or licensee) submitted the FHRR for Surry Power Station (SPS, Surry), Unit Nos. 1 and 2. On December 3, 2015, and December 9, 2015, and February 9, 2016, and March 17, 2016, the staff conducted an audit of the licensee's FHRR submittal (NRC, 2016a). The audit was summarized in the "Nuclear Regulatory Commission Report for the Audit of Virginia Electric and Power Company's Flood Hazard Revaluation Report Submittal Relating to the Near-Term Task Force Recommendation 2.1-Flooding for SPS, Units Nos. 1 and 2" (NRC, 2016d).

On February 29, 2016, the NRC issued an interim staff response (ISR) letter to the licensee (NRC, 2016b). The purpose of the ISR letter is to provide the flood hazard information suitable for the assessment of mitigating strategies developed in response to Order EA-12-049 (NRC, 2012b) and the additional assessments associated with Recommendation 2.1: Flooding consistent with the process outlined in COMSECY-15-0019 (NRC, 2015) and associated guidance. The ISR letter also made reference to this staff assessment, which documents staff basis and conclusions. The flood hazard mechanism values presented in the letter's enclosures match the values in this SA without change or alteration.

As mentioned in the ISR letter (NRC, 2016b), the reevaluated flood hazard results for local intense precipitation (LIP) and associated drainage, failure of dams and onsite water control/storage structures, and storm surge are not bounded by the plant's current design basis (CDB). Consistent with the 50.54(f) letter and amended by the process outlined in COMSECY-15-0019 and Japan Lessons-Learned Division (JLD) Interim Staff Guidance (ISG) JLD-ISG-2016-01, Revision 0 (NRC, 2015 and NRC, 2016c), the staff anticipates that the licensee will perform and document a focused evaluation for LIP and associated site drainage that assesses the impact of the LIP hazard on the site and evaluates and implements any necessary programmatic, procedural, or plant modifications to address this hazard exceedance. The staff also anticipates that the licensee will perform and document a focused evaluation or revised integrated assessment that assesses the impact of the failure of dams and onsite water control/storage structures and storm surge hazard on the site and evaluates and implements any necessary programmatic, procedural, or plant modifications to address this hazard exceedance.

2.0 REGULATORY BACKGROUND

2.1 Applicable Regulatory Requirements

As stated above, Enclosure 2 to the 50.54(f) letter requested that the licensee reevaluate flood hazards at their site(s) 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.

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

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

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

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

2.2 Enclosure 2 to the 50.54(f) Letter

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

2.2.1 Flood-Causing Mechanisms

Enclosure 2 of the 50.54(f) letter (NRC, 2012a) discusses the flood-causing mechanisms that licensees should 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) sections and applicable ISG documents containing acceptance criteria and review procedures.

2.2.2 Associated Effects

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

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

- Groundwater ingress
- Other pertinent factors

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

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

2.2.4 Flood Event Duration

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

2.2.5 Actions Following the FHRR

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

- Submit an interim action plan with the FHRR documenting actions planned or already taken to address the reevaluated hazard.

- Perform an integrated assessment to: (a) evaluate the effectiveness of the 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 each flood-causing mechanism at the site, licensees are not required to perform an integrated assessment.

COMSECY-15-0019 (NRC, 2015) and associated guidance outline 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 a LIP hazard exceeding their CDB flood will not be required to complete an integrated assessment, but would instead perform a focused evaluation. As part of the focused evaluation, licensees will assess the impact of the LIP hazard on their sites and then evaluate and implement any necessary programmatic, procedural, or plant modifications to address the hazard exceedance. For other flood hazard mechanisms that exceed the CDB, licensees can assess the impact of these reevaluated hazards on their site by performing either a focused evaluation or an integrated assessment (NRC, 2015), consistent with JLD-ISG-2016-01, "Guidance for Activities Related to Near-Term Task Force Recommendation 2.1, Flooding Hazard Reevaluation" (NRC, 2016c).

3.0 TECHNICAL EVALUATION

The NRC staff reviewed the information provided for the flood hazard reevaluation of SPS, Unit Nos. 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. Table 3.0-1 provides the summary of controlling reevaluated flood-causing mechanisms, including associated effects, the licensee computed to be higher than the powerblock elevation.

To provide additional information in support of the summaries and conclusions in the FHRR, the licensee made calculation packages available to the staff. The staff relied directly on some of these calculation packages in its review; these calculation packages are cited as part of the audit summary report (NRC, 2016d). 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.

Most elevations in this staff assessment are given with respect to the U.S. Coast and Geologic Survey Mean Sea Level (MSL) datum, which the licensee has adopted as the SPS site datum, which it also sometimes calls Plant Datum (Dominion, 2015). The North American Vertical Datum of 1988 (NAVD88) and National Geodetic Vertical Datum of 1929 (NGVD29) were used for certain elevation measurements. Table 3.1-1 provides conversions between MSL, NAVD88, NGVD29, and other datums referenced in this staff assessment.

3.1 Site Information

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

3.1.1 Detailed Site Information

The SPS site is located in Surry County, Virginia. It occupies a site of approximately 830 acres (336 hectares) on a small peninsula called Gravel Neck that extends into the James River from the south, as shown in Figures 3.1-1 and 3.1-2. The water table in the area is near the ground surface, and there are numerous areas of wetlands which contribute to a substantial amount of the surface water in the area (Dominion, 2015).

The James River has a drainage area of 9,521-mi2 (24,659 km2) above the SPS site (Dominion, 2015). It empties into Hampton Roads at Newport News, Virginia, near the mouth of the Chesapeake Bay (Figure 3.1-2). The 85-mile (220 km) stretch of the James River between Richmond and the mouth of the river is a tidal estuary in which flow is affected by the downstream flow of fresh water, diurnal tides, and the circulation of saline water within the estuary. Near the SPS site, the river is in a transition region between the fresh-water tidal river and saline waters. The licensee states that average mean monthly stream discharge in the James River at the SPS site over the period October 1935 to September 1993 was 10,229 ft3/s (290 m3/s).

Figure 3.1-3 illustrates the general layout of the site, including reactor facilities, intake canal, and discharge canal. Site grade at the power block is elevation 26.5 ft (8.1 m) MSL (Dominion, 2015). Most Class I structures on the power block are protected to this elevation; the control room and the main steam and feedwater isolation valve cubicle have flood protection levels of 27.0 ft and 27.5 ft (8.23 m and 8.38 m) MSL, respectively. The intake canal extends east from the power block to the intake structure located adjacent to the river, approximately 1.25 miles (2 km) from the power block (Figure 3.1-3). The intake canal is not directly connected to the river; water is pumped from the James River into the intake canal. An earthen berm with concrete liner and a top elevation 36.0 ft (11.0 m) separates the intake canal from the site. Normal water elevation at the power-station end of the canal varies between 26.0 ft and 30.0 ft (7.93 m and 9.14 m) MSL. The circulating water intake structure (emergency service water pump house (ESPH) at the intake has openings at 21 ft 2 inches (6.5 m) MSL. During a hurricane or when a hurricane is forecast, seal plates are installed at the ESPH to provide flood protection to 24.0 ft (7.3 m) MSL. During hurricane conditions, air for operation of the diesel-driven emergency service water pumps is supplied through motor-operated dampers located on the top of the ESPH that are protected to elevation 36.0 ft (11.0 m) MSL. The discharge canal is located north of the power block and flows west to the James River.

3.1.2 Design-Basis Flood Hazards

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 licensee states that there have been no changes to the current licensing basis flood elevations subsequent to the Surry UFSAR Rev. 46.02 (Dominion, 2014). The NRC staff reviewed the information provided in the SPS FHRR (Dominion, 2015) and determined that sufficient information was provided to be responsive to Enclosure 2 of the 50.54(f) letter (NRC, 2012a).

3.1.4 Changes to the Watershed and Local Area

The licensee states that there have been no site changes or changes to the watershed in the vicinity of the site since issuance of the 2014 Updated Final Safety Analysis Report (Dominion, 2014) that would impact flood hazards. There are no known or planned river control structures on the James River. Several small impoundments have been established on tributaries to the upper reaches of the river, but due to their size and location, they do not affect flood hazard at the site. The NRC staff reviewed the information provided in the SPS FHRR (Dominion, 2015) and determined that sufficient information was provided to be responsive to Enclosure 2 of the 50.54(f) letter (NRC, 2012a).

3.1.5 Current Licensing Basis Flood Protection and Pertinent Flood Mitigation Features

The licensee stated in its FHRR that two events are considered as causes for external flooding in the CLB (Dominion, 2015). These are probable maximum flood (PMF) of the James River due to watershed runoff and/or surge due to severe storms and probable maximum hurricane (PMH) surge (including effects on the intake structure and intake canal).

The PMF event considered in the CLB results in a 1 ft (0.3 m) rise in the normal river level and is therefore bounded by the PMH. There are no flood protection measure considered for the James River PMF event since it does not produce limiting flood levels affecting Class I structures.

The PMH still water elevation in the CLB is estimated to be 22.7 ft (6.92 m) MSL, and with wind wave runup results in a water surface elevation of 28.6 ft (8.72 m) MSL on the east side of the plant and 24.0 ft (7.32 m) MSL on the west side of the plant (Dominion, 2015). For the PMH flood event, the CLB does not specifically address plant configuration (modes of operation) due to the CLB event. For the PMH event, the intake structure is located 1.25 miles (2.01 km) east of the SPS power block and is protected by water tight seals and doors up to 24 ft (7.3 m) MSL. Additionally, the elevation of the diesel emergency service water pumps located at the intake have exhaust hoods with a center line elevation of 36.5 ft (11.13 m) MSL. The site grade at the power block on the west side of the SPS site is 26.5 ft (8.08 m) MSL and therefore protected from a PMH event. The NRC staff reviewed the information provided in the SPS FHRR (Dominion, 2015) and determined that sufficient information was provided to be responsive to Enclosure 2 of the 50.54(f) letter (NRC, 2012a).

3.1.6 Additional Site Details to Assess the Flood Hazard

The licensee provided model input data and supporting calculation packages for staff's review (NRC, 2016d). The data included analyses performed for James River PMF, PMH, and LIP flooding. The NRC staff reviewed the information provided in the SPS FHRR (Dominion, 2015) and determined that sufficient information was provided to be responsive to Enclosure 2 of the 50.54(f) letter (NRC, 2012a).

3.1.7 Results of Plant Walkdown Activities

In response to Enclosure 4 of the 50.54(f) letter (NRC, 2012a), the licensees provided its flood walkdown report for SPS by letter dated November 27, 2012 (Dominion, 2012). The staff concluded that the licensee's implementation of the flooding walkdown methodology met the intent of the walkdown guidance, as documented in the walkdown staff assessment, dated June 25, 2014 (NRC, 2014b).

3.2 Local Intense Precipitation and Associated Site Drainage

The licensee reported in its FHRR that the reevaluated flood hazard, including associated effects, for LIP, and associated site drainage is based on a stillwater-surface elevation of 29.4 ft (8.9 m) MSL (Dominion, 2015). Additional effects of wind waves and runup were not considered, as their effects are judged to be inconsequential. This flood-causing mechanism is not discussed in the licensee's CDB.

The licensee used the two-dimensional hydrodynamic computer model FLO-2D Pro (FLO-2D, 2014a), Build No. 14.03.07, in its assessment of the flood hazard from LIP. A 426-acre (172.4 hectares) drainage area was modeled, including the SPS site and the intake canal and discharge canal. An aerial photogrammetric survey conducted in 2012 provided topographic data for the SPS and U.S. Geological Survey (USGS) National Elevation Dataset provided data for portions of the drainage area outside the limits of the photogrammetric mapping. The drainage area was modeled with a uniform grid of square elements, 15 ft by 15 ft (4.6 m by 4.6 m). The canals were modeled as channel segments and the settling pond was modeled as a detention basin with grid elevations equal to the normal pool elevation of 32.5 ft (9.91 m) MSL. Buildings were treated as elevated grid elements at least 5 ft (1.5 m) higher than surrounding topography, so rainfall incident to roofs would be evenly distributed onto surrounding areas. Vehicle barrier system (VBS) locations and properties were determined from the aerial survey and site visits. The VBS was modeled as levees with specific height based on direct measurements of the VBS, and 2 ft (0.6 m) openings in the VBS were modeled as weirs. Manning's roughness (n) values were assigned based on site conditions, using guidance in the FLO-2D manual (FLO-2D, 2104b), and ranged from 0.02 for concrete and asphalt, including building roofs and the concrete-lined intake canal, to 0.3 for areas with tree and shrub vegetation. The discharge canal was assigned a Manning's n value of 0.04 (the same value assigned to gravel) to account for the roughness of its Fabriform concrete liner. The entire drainage area was assumed to be impervious, with zero infiltration, and storm drains were assumed to be nonfunctional. Movable barriers in the VBS were assumed to be closed, which the licensee states is conservative because their closure could prevent water from exiting the site. The probable maximum precipitation (PMP) rainfall event for the licensee's simulation of LIP effects was a 6 hour (-h) PMP event that included a 1-h PMP event at its peak. Two precipitation analyses were performed for the site:

1. Precipitation based on HMR 52
2. Precipitation based on a site-specific meteorological study

Each of these analyses are further described below.

The licensee's initial analyses of LIP effects considered a 1-h PMP value of 18.6 in (47.2 cm) depth that was determined for a 1-mi2 (2.6 km2) area using Hydrometeorological Report (HMR) 52 from the National Oceanic and Atmospheric Administration (NOAA) (NOAA, 1982) methodology, occurring within a 6-h PMP event of 28.8 in (73.2 cm) determined for a 10-mi2 (25.9 km2) area using HMR 52. The licensee analyzed the sensitivity of water levels in the plant area to different timings of peak PMP within the 6-h PMP event. Rainfall increments within the peak hour were split into 5-minute increments according to guidance in HMR 52, and the remainder of the 6-h PMP was evenly distributed throughout the other 5 hours of the event. The sensitivity analysis considered a front-loaded temporal rainfall distribution (that is, the most intense 5-minute and 1-h rainfall occur at the beginning of the 6-h event), a middle-loaded distribution, and an end-loaded distribution. The analysis found that locating the most intense part of the PMP event later in the storm results in more conservative flood depths. With peak 1-h rainfall of 18.6 in (47.2 cm) based on HMR 52, maximum simulated flooding depths at locations of interest were up to 1.0 ft (0.30 m) higher for a middle-loaded rainfall distribution and up to 1.2 ft (0.35 m) higher for an end-loaded distribution than for a front-loaded distribution.

In addition to the aforementioned analysis based on HMR 52, the licensee also conducted a site-specific meteorological study to determine 1-h PMP and 6-h PMP values for a 1-mi^2 (2.6 km^2) area. The licensee states that its approach was consistent with recommendations in ANSI/ANS-2.8-1992 (ANSI/ANS, 1992) and followed guidance in HMR 53 (NOAA, 1980) and the World Meteorological Manual for PMP determination (WMO, 2009). The 1-h and 6-h site-specific PMP values identified for the analysis were 12.4 in and 28.8 in (31.5 cm and 73.15 cm), respectively. The site-specific study found that the 1-h PMP event was most likely to occur in either the second hour of the storm or the fourth hour of the storm. Considering the sensitivity analysis that showed more conservative results from a later peak rainfall, the licensee constructed a 6-h PMP hyetograph including the peak 1-h PMP event during the fourth hour. Rainfall increments within the peak hour were distributed in 5-minute increments according to guidance in HMR 52, and the remainder of the 28.8-in (73.15 cm) 6-h PMP was evenly distributed throughout the other 5 hours of the event.

The licensee considered the effects of a LIP event under two different plant operating cases: (1) plant is fully operational and 3,921 ft3/s of (111 m3/s) water (the total cooling flow for the two reactor units) is withdrawn from the intake canal and (2) plant is shut down and normal withdrawals of cooling water from the intake canal do not occur (Dominion, 2015). When Case 2 was simulated with HMR 52 PMP values, the only removal of water from the Intake Canal was that which occurred by overtopping of the berm. Spillage of water from the intake canal occurred, increasing water levels in the plant area by no more than 0.1 ft (0.03 m) compared to Case 1. When Case 2 was simulated with site-specific PMP values, the licensee assumed that when the water level in the intake canal exceeded the normal maximum level of 30 ft (9.1 m) MSL, a minimum flow of 980 ft3/s (27.8 m3/s) would be released from the Intake Canal through four water box outlets that are provided to control the maximum water level in the canal. With this assumption, water elevations in the plant area were the same for Case 1 and Case 2. For Case 1, the licensee's analysis that used HMR 52 values for PMP in an end-loaded temporal rainfall distribution (the most conservative PMP event analyzed) predicted water levels that were as much as 0.8 ft (0.24 m) higher than the corresponding water surface elevations predicted with site-specific PMP values and peak rainfall in the fourth hour of the storm. The NRC staff's review considered the results of the analysis based on site-specific PMP values.

In its FHRR, the licensee reported maximum water surface elevations and water depths at grid elements representing 57 "strategic door" locations identified by SPS personnel (Dominion, 2015). Calculated water surface elevations from LIP flooding resulting from site-specific PMP exceeded the threshold elevations of all but six doors. The highest calculated water surface elevation at a door location is 29.4 ft (8.96 m) MSL at the doors (Doors 17 and 18) into the Maintenance Building at the southeastern part of the site resulting in a ponding depth of 2.9 ft (0.88 m) above nominal site grade. Water depth at those doors would be 2.4 ft (0.72 m) above local grade. Maximum calculated flow velocities during LIP are as high as 5.0 ft/s (1.5 m/s), which the licensee states is unlikely to result in debris loading issues. The licensee states that hydrodynamic and hydrostatic loading are likely to be minimal due to generally shallow water depths and low velocities.

The NRC staff reviewed the licensee's descriptions of its analyses and its rationale for the selected approaches to evaluating effects of LIP, compared input parameters against the cited technical references, examined the licensee's FLO-2D input files and verified that the analysis had been conducted as reported, ran FLO-2D to confirm the licensee's results, and conducted limited sensitivity analysis using FLO-2D. Through this review, the staff confirmed that the licensee's reevaluation of the hazard from local intense precipitation and associated drainage used present-day methodologies and was consistent with current regulatory guidance.

The staff confirmed the licensee's conclusion that the reevaluated flood hazard for local intense precipitation and associated site drainage is not bounded by the CDB flood hazard. Therefore, the NRC staff concludes that the licensee will need to submit a focused evaluation for local intense precipitation and associated site drainage flood-causing mechanism for SPS, Units 1 and 2, consistent with the process and guidance discussed in COMSECY-15-0019 (NRC, 2015).

3.3 Streams and Rivers

The licensee reported in the FHRR that the reevaluated flood hazard, including associated effects, for streams and rivers is based on a stillwater elevation of 12.1 ft (3.69 m) MSL. Including wind waves and runup, this flood level will remain below the plant grade and could not affect components important to safety which are protected to against a flood level of 24.0 ft (7.32 m) MSL (Dominion, 2015). This flood-causing mechanism is discussed in the licensee's CDB, but no flood elevation was reported.

3.3.1 Probable Maximum Flood on Streams and Rivers

As a first step in its analysis of flooding from streams and rivers, in the FHRR (Dominion, 2015) the licensee delineated the 9,521-mi^2 (24,659 km^2) James River watershed above the SPS site using USGS Hydrologic Unit data included in the National Hydrography Dataset (NHD) (USGS, 2012) and Digital Elevation Model (DEM) data (Gesch et al., 2002). The watershed was subdivided into three subwatersheds, denoted as the Upper James River, the Appomattox River, and the Lower James River watersheds (Figure 3.3-1). The Upper James River watershed (6,753 mi^2) (17,490 km^2) and the Appomattox River watershed (1,334 mi^2) (3,455 km^2) are gauged, but the Lower James River watershed (1,434 mi^2) (3,714 km^2) is ungauged (Dominion, 2015).

As described in its FHRR (Dominion, 2015), the licensee used the BOSS HMR 52 computer program (Boss International, 1988), which is based on methodologies in HMR 51 and HMR 52, to calculate all-season PMP for this watershed. The controlling all-season PMP was determined to be a 72-hour event with a total rainfall depth of 15.1 in (38.35 cm) for the watershed as a whole, including 15.5 in (39.37 cm) for the Upper James River watershed above Richmond, 15.9 in (40.39 cm) for the Appomattox River watershed above Dinwiddie, and 12.6 in (32.0 cm) for the Lower James River watershed above the SPS site. Methods from HMR 53 (NOAA 1980) and an energy budget method presented in U.S. Army Corps of Engineers (USACE) Engineering Manual 1110-2-1406 (USACE, 1998) were used to check whether cool-season PMP combined with snowmelt could lead to a more severe flood than predicted based on all-season PMP. The combined 72-hour cold season PMP and extreme snowpack melt values for each of the three subwatersheds were found to be smaller than the corresponding all-season PMP values for the subwatersheds, so the all-season PMP values were determined to be controlling. The NRC staff reviewed the licensee's descriptions of its analyses in the FHRR and calculation packages (NRC, 2016d) and compared the analyses with the cited technical references. The reviewed technical references and calculation packages are referenced in the Audit Summary report dated August 12, 2016 (NRC, 2016d). Through this review, staff confirmed that the licensee had applied current methodologies and valid engineering judgment in this part of the analysis.

As described in its FHRR (Dominion, 2015), the licensee used Hydrologic Engineering Center-Hydrologic Modeling System (HEC-HMS) software (USACE, 2010b) to model watershed hydrology. The licensee chose the Snyder unit hydrograph method to transform precipitation into streamflow. Initial input values for the basin lag time and peaking coefficient parameter were based on mid-range values recommended for this method. Initial estimates of the constant loss rate parameter, which describes the infiltration characteristics of watershed soils were developed from analysis of soil characteristics of the watersheds based on data from the Natural Resources Conservation Service (NRCS) GIS State Soil Geographic (STATGO) Database for the United States. The licensee used the minimum infiltration rate for each hydrologic soil group classification, as given in Table 5.1 of the HEC-HMS Technical Reference Manual (USACE, 2000).

For the two gauged subwatersheds, the rainfall-runoff model was calibrated against hydrographs developed from USGS daily stream flow data and associated National Climatic Data Center (NCDC) rainfall data for three large single-event storms that occurred during May through October (when snowmelt would not contribute to streamflow) and produced flooding in the specific subwatershed (Dominion, 2015). Thiessen polygons were used to yield an area-weighted precipitation gage weight for input into the HEC-HMS model. The subwatershed models were calibrated to observed USGS stream flow data by making adjustments to the basin lag time, peaking coefficient, initial loss, and constant loss rate. Subsequently, three additional verification storms that met the same criteria as the storms used for calibration were modeled for each subwatershed to validate specific values for the four input parameters that were adjusted during calibration. For the Upper James River watershed, comparison of modeled peak flow with observed peak flows showed "acceptable agreement" with the greatest differential in peak flows being 3 percent. For the Appomattox River subwatershed, comparison of observed and modeled peak flow showed "acceptable agreement" with observed peak flows with the greatest differential in peaks for the calibration storms being 10 percent for the calibration storms and 30 percent for the verification storms. The licensee attributed the latter discrepancy to a decision to ignore penstock/turbine discharges at Brasfield Dam (the only dam considered in the model) in modeling, which is conservative because it limits the effect of reservoir storage on model predictions. Input parameters developed for the Upper James River watershed were also used in modeling the ungauged Lower James River watershed, which was judged to have similar hydrologic characteristics.

The calibrated HEC-HMS model of the James River watershed was used to simulate the streamflow hydrograph for the PMF. The modeled event was based on the all-season 72-hr PMP. The input hyetograph to the PMF was constructed using an antecedent storm consisting of 40 percent of the PMP depths during the first 72 hours, followed by a 72-hour dry period, and finally followed by the full 72-hour PMP storm. Baseflow at the beginning of the event was determined from streamflow data for the gauged watersheds and estimated for the Lower James River watershed based on flow data from the Upper James River watershed. Non-linearity adjustments were made to the Snyder unit hydrographs in accordance with the NUREG/CR-7046 (NRC, 2011e) recommendation to increase the peak discharge of the unit hydrograph by 20 percent and decrease the time to peak by 33 percent to account for the expectation that the PMF will be significantly larger than the calibration or verification floods. For the PMF simulation, the initial loss parameter was conservatively set to zero. The resulting calculated estimate of the PMF discharge on the James River at Surry was 867,300 ft^3/s (24,559 m^3/s).

The staff reviewed the licensee's description of its hydrologic analysis, examined the HEC-HMS input files provided by the licensee, and ran the PMF simulation using the licensee's input files to confirm the licensee's results. This review confirmed that the licensee's analysis was based on conservative assumptions and used present-day methodologies.

The licensee used HEC-River Analysis System (RAS) (USACE, 2010a), with flood hydrograph data generated by HEC-HMS, to determine the hydraulic profile of flooding in the lower James River resulting from the PMF event. A 100-mile-long (161 km) reach of the James River was modeled, beginning approximately 50 miles (80.5 km) upstream from the SPS site and extending downstream to the confluence of the James River and the Atlantic Ocean. The downstream boundary condition was assigned as a constant-stage hydrograph of approximately 3.1 ft (0.94 m) MSL, corresponding to the Mean Higher High Water elevation at the Chesapeake Bay Bridge Tunnel tide gauge (see Figure 3.1-2). Manning's n values for the channel and overbank were set at 0.04 and 0.10, respectively. The NRC staff confirmed that this approach used present-day methodologies and was based on current regulatory guidance, and found the licensee's input values to be conservative.

The HEC-RAS analysis determined a peak PMF stillwater elevation near the SPS site to be 11.5 ft (3.51 m) NGVD29, reported in the FHRR as 12.1 ft (3.69 m) MSL, which is 14.4 ft (4.39 m) below the site grade of 26.5 ft (8.08 m) MSL (Dominion, 2015). The NRC staff examined the HEC-RAS input files provided by the licensee and ran the simulation using the licensee's input files to confirm the licensee's results.

3.3.2 Conclusion

In summary, the NRC staff review confirmed that the licensee's reevaluation of the flood hazard for rivers and streams was based on current regulatory guidance and used present-day methodologies. The staff confirmed the licensee's conclusion that the reevaluated hazard from flooding from streams and rivers alone would not inundate the site. Therefore, the NRC staff concludes that the licensee will not need to submit an additional assessment for rivers and streams flood-causing mechanism for SPS, Units 1 and 2, consistent with the process and guidance discussed in COMSECY-15-0019 (NRC, 2015).

3.4 Failure of Dams and Onsite Water Control/Storage Structures

The licensee reported in its FHRR, that the reevaluated flood hazard, including associated effects, for failure of dams and onsite water control or storage structures is based on a stillwater-surface elevation of [redacted] (Dominion, 2015). This flood-causing mechanism is discussed in the licensee's CDB, but no flood elevation was reported.

The licensee's reevaluation of flood hazard for failure of dams and onsite water control or storage structures considered three potential sources of flooding: (1) failure of upstream dams, (2) failure of the onsite intake canal, and (3) failure of the onsite settling pond (Dominion, 2015). Water levels in the two onsite water control structures are above the site grade elevation.

3.4.1 Upstream Dams

To evaluate the potential flood hazard from failure of upstream dams, the licensee considered the potential hydrologic failure of all upstream dams coincident with a PMF in the James River

(Dominion, 2015). Consideration of this hydrologic failure scenario is conservative, as upstream reservoir levels and river flows would be higher than for a seismic failure or a sunny-day failure. The licensee consulted the National Inventory of Dams maintained by the USACE (USACE, 2013) to obtain a list of 745 upstream dams located in the James River watershed. Five groupings of dams were developed for the Upper James River watershed, the Appomattox River watershed, and the Lower James River watershed. The dams in each subwatershed grouping were grouped and modeled as a single hypothetical dam located at the downstream outlet of the subwatershed; for the Lower James River watershed, the hypothetical dam was located adjacent to the SPS site. The height of the hypothetical dam was set equal to the height of the highest dam in the subwatershed, and peak breach flow from failure of the hypothetical dams was calculated using three regression equations of Froehlich (2008), MacDonald and Langridge-Monopolis (1984), and Costa (1985).

The licensee used the HEC-RAS model to determine flooding effects at the SPS site (Dominion, 2015). The licensee calculated a combined peak flow rate of [redacted] in the James River at the SPS site, resulting in a peak flood elevation of [redacted] at a cross-section adjacent to the SPS site. This value is well below the site grade of 26.5 ft (8.08 m) MSL. The NRC staff performed confirmatory simulations, reviewed the results, and determined that the analysis was performed as described and confirmed the licensee's results.

3.4.2 Intake Canal

For failure of the onsite intake canal, the licensee eliminated hydrologic failure from consideration, citing analyses that show that the dam would not fail due to overtopping (Dominion, 2015). The licensee stated that seismic failure of the intake canal could be screened out, noting that the NRC had determined (NRC, 2014a) that the safe shutdown earthquake (SSE) bounds the ground motion response spectrum for the SPS. Therefore, seismic failure of the intake canal, which is listed in UFSAR Chapter 15, Table 15.2-1 (Dominion, 2014), as a Seismic Class I component or structure, is not credible. The staff confirmed that the licensee's reasoning for eliminating these failure modes was consistent with current regulatory guidance.

After screening out the other failure modes, the licensee evaluated the consequence of a sunny-day failure of the Intake Canal embankment. The analysis considered three potential failure locations on the north side of the embankment near the SPS facilities. Breach parameters for the embankment were developed based on values from regulatory guidance and dam-breach regression equations (NRC 2013b, FERC, 1993, and Froehlich, 2008). The breach width was estimated as [redacted] and height was [redacted] time to failure was estimated as [redacted] Flooding effects from the breach event would be similar in kind to the effects of an LIP event and were modeled using the FLO-2D model used to evaluate LIP flooding. [redacted] which is less than the corresponding flood elevation from an LIP event. Maximum water velocity was estimated as [redacted]

3.4.3 Settling pond

For the settling pond, the licensee identified a hydrologic failure of the pond embankment as credible and the most severe potential failure (Dominion, 2015). The analysis considered the possibility that the embankment would fail due to overtopping at 35 ft (10.7 m) MSL during an LIP event. Breach was assumed to occur at the southwestern end of the Settling Pond embankment (the location closest to the SPS facilities). Breach parameters for the embankment were developed on the same basis as for the intake canal embankment and included breach height of [redacted] breach width of [redacted], and time to failure [redacted] The FLO-2D model was used to model the effects. The analysis found that, due to site topography, water from the settling pond would drain into the discharge canal and there would be no flooding of site facilities.

3.4.4 Conclusion

The staff confirmed the licensee's conclusion that the reevaluated flood hazard for failure of dams and onsite water control or storage structures is not bounded by the CDB flood hazard. Therefore, the NRC staff determined that flooding from failure of onsite water control or storage structures would need to be analyzed in a focused evaluation or an additional assessment, consistent with the process discussed in COMSECY-15-0019 (NRC, 2015) and associated guidance.

3.5 Storm Surge

The licensee reported in its FHRR that the deterministic reevaluated flood hazard, including associated effects, for site flooding due to storm surge is based on a stillwater elevation of 24.2 ft (7.38 m) MSL on the east side of the plant (Dominion, 2015). Including wind waves and runup results in an elevation of 38.8 ft (11.83 m) MSL at the SPS low level intake structure and 39.9 ft (12.16 m) MSL at the SPS Level Intake Embankment, both of which are on the east side of the plant. The deterministic reevaluated flood hazard, including associated effects, for site flooding due to storm surge is 24.2 ft (7.38 m) MSL on the west side of the plant where wave effects were determined to be minimal.

This flood-causing mechanism is discussed in the licensee's CDB (Dominion, 2015). The maximum stillwater CDB elevation due to surge is 22.7 ft (6.92 m) MSL on the west and east sides of the site. The CDB total water surface elevations are 24.0 ft (7.32 m) MSL and 28.6 ft (8.72 m) MSL for the west and east sides of the site, respectively. These CDB values are reflected in the ISR letter (NRC, 2016a).

The licensee provided both a probabilistic and a deterministic storm surge flood hazard analysis in its response to the 50.54(f) letter (Dominion, 2015 and NRC, 2016d) and determined that the deterministic evaluation is more conservative. The staff reviewed both the deterministic and probabilistic analysis provided by the licensee and agrees that the deterministic storm surge evaluation is more conservative. Further information on the staff's review of both the licensee's probabilistic and deterministic storm surge analysis can be found in an analysis conducted by Taylor Engineering (2016). This SA focuses on the staff's review of the deterministic storm surge analysis.

3.5.1 Licensee's Deterministic Storm Surge Analyses

3.5.1.1 Historical Data

The licensee reported in its FHRR (Dominion, 2015) that they performed the reevaluated storm surge analysis using guidance outlined in NUREG/CR-7046 (NRC, 2011e). The licensee described in its FHRR historical storm surge data, including region-specific hurricane climatology, to develop a conservative set of synthetic hurricane meteorological parameters. Additionally, the licensee reviewed water elevation data from nearby NOAA CO-OPS stations to identify the events that produced historical extreme water surface elevations and to compare model results. The licensee reviewed historical storm tracks and correlated these with many of the historical high water surface elevation data. The licensee stated that, based on the review of historical data, the probable maximum storm surge (PMSS) would be from a PMH.

The staff determined that the licensee's historical storm surge data was sufficient. Additionally, the licensee provided the details to support their deterministically-developed PMH and identified and described an acceptable PMH.

3.5.1.2 Antecedent Water Level

The licensee calculated an antecedent water level (AWL) using data obtained from Sewells Point, Virginia (Dominion, 2015). The licensee reported a 10 percent exceedance high tide of 3.5 ft (1.07 m) NAVD88 based on monthly maximum tide data observed at the Sewells Point, Virginia NOAA tidal gauging station (NOAA Station ID 8638610). The licensee accounted for sea level rise (SLR) using a 50-year period for SLR rates estimated at this station, but did not provide the SLR rate. The licensee stated that the AWL, including the 10 percent exceedance high tide and SLR, was determined to be 4.3 ft (1.31 m) NAVD88.

The staff independently evaluated the AWL accounting for a 10 percent exceedance high tide and a 50-year sea level rise for the site. The staff AWL estimate was 3.8 ft (1.17 m) NAVD88 (Taylor Engineering, 2016). The staff concluded that the licensee's estimated was reasonable.

3.5.1.3 Surge Model Application Methodology

The licensee used the NOAA Sea, Lakes, and Overland Surges (SLOSH) (NOAA, n.d., and NOAA, 1992) model for its initial ranking of storms based on estimated storm surge levels and developed a refined storm set based on that ranking (Dominion, 2015). The initial storm set was developed based on the NWS 23 PMH parameters, and with a range of storm bearings and landfall locations. The licensee used the SLOSH model results to assess the sensitivity of the storm surge at the site for different storm parameters and ranked the storm parameter sets accordingly. The licensee used the SLOSH results to refine the storm set to be further evaluated using Advanced Circulation Model (ADCIRC) (Dominion, 2015; USACE, 1994). The refined set of 15 storms include specification of five different storm bearings, three different landfall locations, three different forward speeds, and three different radii of maximum winds. The timing of the storm landfall was adjusted to occur one hour prior to high tide. The licensee reported the one hour lag in storm landfall timing produced maximum surge elevations at the SPS. The licensee found that, with the refined storm set, the storm parameters where a track direction -60 degrees (i.e., tracking towards the northwest), landfall position of 35.913N, 75.596W, radius of maximum of 35 nm (65 km), forward speed of 15 kt (28 km/h), maximum 1-

min, 10-m overland wind speed of 119.9 kt (61.68 m/s), and central pressure deficit of 2.9 in-Hg (98 mb).

The licensee used ADCIRC to estimate the maximum stillwater elevations (SWE) for each of the refinement storm set cases and to identify the storm that produced the PMSS SWE. The licensee used the deterministic PMSS results from three storms as input to the ADCIRC+SWAN model to estimate wave effects (Dominion, 2015). The licensee stated that most waves will move "away from the site (i.e. predominately in the southwest and northeast directions)." The licensee applied the ARCIRC+SWAN model to include the simulation of wave with the worst storm (Hurricane Isabel) surge in the evaluation of the deterministic combined effect flood. The licensee performed many SLOSH simulations to identify storm parameters that significantly impact storm surge at the site and the 15 sets of storm parameters that produce the highest predicted storm surges at the site (Dominion, 2015). The licensee thereby identified a refined storm set for further evaluation. The licensee performed five ADCIRC simulations to determine the sensitivity of the maximum surge at the site with the timing of the storm arrival time. The licensee used this information to adjust the landfall timing of the storm arrival with tidal conditions. The licensee added a 0.8 ft (0.24 m) to the deterministic combined effects flood maximum SWE to account for uncertainty effects. The staff determined that licensee applied appropriate storm parameters and conditions for the SLOSH model storm screening, ADCIRC, and ADCIRC+SWAN models (Taylor Engineering, 2016).

3.5.1.4 Surge Model Results

The licensee identified the set of storm parameters that produced the PMSS at the site discharge location and the site intake locations (Dominion, 2015). These were 21.3 ft (6.49 m) NAVD88 (22.7 ft (6.93 m) MSL) and 20.9 ft (6.37 m) NAVD88 (22.3 ft (6.81 m) MSL), respectively. The deterministic combined effect flood maximum water elevation was 24.2 ft (7.38 m) MSL, which is a combination of maximum modeled SWE (including wave setup and 25-year river flood flow) of 21.0 ft (6.40 m) MSL, uncertainty effects of 0.8 ft (0.24 m), and difference between the peak simulated tide elevation at Sewells Point, Virginia, and the AWL of 2.4 ft (0.72 m) (which includes SLR).

3.5.1.5 Wave Effects

The licensee estimated wave characteristics along the SPS shoreline under three alternative flood scenarios for the SPS:

- The first alternative included the one-half James River PMF, static antecedent 10 percent exceedance high tide and the wind-field associated with the worst regional hurricane. The licensee calculated a maximum water surface elevations of 13.3 ft (4.05 m) MSL and 13.8 ft (4.21 m) MSL at the site intake and discharge canals, respectively, for this alternative.
- The second alternative included the James River PMF, 25-year surge height, and 10 percent exceedance high tide. The licensee calculated a maximum water surface elevation of 15.5 ft (4.72 m) MSL at the site for this alternative.
- The third alternative included the 25-year James River flow, and the deterministic PMSS for several storm events. The licensee calculated a maximum stillwater elevation of 24.2 ft (7.38 m) MSL and 24.1 ft (7.35 m) MSL at the SPS intake and discharge canals, respectively, for this alternative. The licensee used this alternative to characterize the flood hazard and as input to the calculation of other associated effects (Dominion, 2015).

The licensee estimated wave runup at the SPS intake embankments using the Technical Advisory Committee for Water Retaining Structures method (USACE, 2006). The licensee used the deterministic PMSS and ASCE 7-10 guidance to characterize depth-limited standing wave crest elevations. The licensee determined that PMSS conditions will results in a "small portion of inundation encroaching upon the site." The licensee judged that existing vegetation and presence of groins would inhibit the formation of waves in the discharge canal area and therefore wave runup effects are negligible on the western portion of the site.

3.5.2 Staff's Independent Deterministic Storm Surge Analysis

The staff conducted an independent meteorological analysis to determine a track, intensity, translation speed, and wind structure that is judged to generate the maximum surge in a deterministic storm surge simulation. The staff used NWS 23 to establish initial storm parameter values. The staff revised and supplemented the NWS 23 information based on newer observations than where incorporated in NWS 23 (Taylor Engineering, 2016).
The staff completed an independent review of local vertical datums at the Sewells Point, VA NOAA station. The staff found that NOAA data indicate a smaller difference between NAVD88 and MSL difference than the licensee used. This difference does not appear to be of significant concern, as application of the staff conversion would decrease surge flood hazard elevations relative to those presented by the licensee in its FHRR (Taylor Engineering, 2016).

The NRC staff independently developed a deterministic PMSS for the site by application of the SWAN+ADCIRC model using a pre-existing Federal Emergency Management Agency (FEMA) model configuration for the region. The staff demonstrated that the model produced results consistent with FEMA's prior results for a validation case (Hurricane Isabel). The staff then developed 25 sets of storm parameters including time-varying two-dimensional wind and pressure filed for tropical storm. The staff applied these 25 storm parameter sets as inputs to the ADCIRC model. The staff reviewed the results of the ADCIRC model, and developed a reduced set (nine) of storm parameters as inputs to the SWAN+ADCIRC model. The SWAN+ADCIRC model couples a hydrodynamic and spectral wave models to allow for calculation of wave-induced water surface elevation effects near the site. The staff determined that the licensee's deterministic stillwater elevations were consistent with the staff's independently developed stillwater elevations (Taylor Engineering, 2016).

The staff performed an independent technical evaluation of side slope at the intake embankment for the wave effects scenarios described by the licensee using information provided in the FHRR (Dominion, 2015) and the USACE Coastal Engineering Manual (USACE, 2011). The staff's independent evaluation confirmed the licensee's wave-runup estimation was reasonable (Taylor Engineering, 2016).

The staff confirmed the licensee's conclusion that the reevaluated hazard for flooding due to storm surge is not bounded by the CDB flood hazard at the SPS site. Therefore, the NRC staff determined that flooding from storm surge needs to be analyzed in a focused evaluation or an additional assessment consistent, with the process and guidance discussed in COMSECY-15-0019 (NRC, 2015).

3.6 Seiche

The licensee reported in its FHRR that the reevaluated hazard, including associated effects, for site flooding from seiche does not inundate the plant site. This flood-causing mechanism is not expected to cause flooding in the licensee's CDB (Dominion, 2015).

The licensee evaluated seiche at the SPS site with consideration of meteorological, astronomical, and seismic forcing as the causative mechanism for low frequency water surface oscillations or seiche in the James River, the intake canal, and the discharge canal. The licensee applied the hierarchical-hazard assessment approach (HHA) described in NUREG/CR-7046 (NRC, 2011e) to determine whether a seiche in either the James River or the intake and discharge channels could result in a significant flooding event (Dominion, 2015).

The licensee applied Merian's Formula to evaluate both semi-enclosed and enclosed basins (Scheffner, 2008 and Rabinovich, 2009). The FHRR states that the James River measures approximately 310,000 ft (94,488 m) from Sewell's Point to Tettington and 425,000 ft (129,540 m) from Sewell's Point to Hopewell (Dominion, 2015). The licensee obtained water depths from the NGDC database (NOAA, 2012a). Merian's Formula predicted a seiche period of 10 to 12 hours using Tettington as a reflection point, and 13 to 16 hours using Hopewell as a reflection point. The licensee also evaluated the natural period by performing a spectral analysis on 3 months of data from NOAA stations (NOAA, 2012b) with no seiche dynamics observed in the James River.

The FHRR states that the 100-foot (30.5 m) wide intake canal runs 9,200 ft (2,804.16 m) from the east side of the peninsula to the plant (Dominion, 2015). The discharge canal varies in width from 100 ft (30.5 m) to 140 ft (42.7 m) and runs 3,500 ft (1,066.80 m) from SPS to the west side of the peninsula, where it is open to the river. The licensee states that the depths in the intake canal range from 20 to 25 ft (6.10 to 7.62 m) and the tidal range of the discharge canal depths is 16.1 ft to 18.9 ft (4.91 m to 5.76 m). The licensee calculated periods for the intake and discharge canals in the longitudinal and transverse directions with ranges of 11 to 12 minutes and 9 to 10 minutes, respectively, in the longitudinal direction. In the transverse direction, the periods range from 7 to 8 seconds and 8 to 12 seconds for the intake and discharge canal, respectively.

The FHRR states that the typical frequency content of earthquakes typically do not exceed 10 seconds (Dominion, 2015). The James River response spectra showed only small acceleration at the 7 to 12 second range. Similarly, the licensee concludes that external forcing by tsunami (several minutes to 1 hour), meteorological events (1 minute) and tides (semidiurnal) would not support seiche oscillatory behavior in the James River and intake/discharge canal.

The NRC staff applied the seiche equations presented in the CEM (Coastal Engineering Manual) (USACE, 2002). The FHRR variously states the depth range of the intake canal which spans from 20 to 30 ft (FHRR Sections 1.5.1 and 2.5.2.3). The staff used Merian's formula and found that the intake channel natural period could differ from those reported by the licensee due to the various depth ranges reported by the licensee but would not do so by an amount that would yield a different conclusion than that made by the licensee. The staff confirmed the licensee's conclusions for the James River, intake canal and discharge canal. The NRC staff also reviewed the licensee's reference articles and confirmed the licensee's statements regarding wind, seismic and tidal effects on seiche resonance.

In summary, the NRC staff confirmed the licensee's conclusion that the PMF from seiche alone could not inundate the SPS site. The NRC staff confirmed that the reevaluated hazard for flooding from seiche is bounded by the CDB flood hazard. Therefore, the NRC staff determined that the seiche flood-causing mechanism does not need to be analyzed in a focused evaluation or an additional assessment consistent with the process and guidance discussed in COMSECY-15-0019 (NRC, 2015).

3.7 Tsunami

The licensee reported in its FHRR that the reevaluated PMF elevation, including associated effects, for site flooding due to tsunami is 5.5 to 5.7 ft (1.69 to 1.74m) NAVD88. This flood-causing mechanism is not expected to cause flooding at the SPS site (Dominion, 2015). This flood-causing mechanism is discussed in the licensee's CDB, but no flood elevation was reported.

The FHRR discusses three possible mechanisms for tsunamis: submerged landslides, volcanic cone collapse, and a subduction zone earthquake (Dominion, 2015). Information about each of the possible sources was obtained from published scientific literature (Grilli et al, 2011, 2013a and 2013b; ten Brink et al, 2008; and NGDC, 2012) to establish the probable maximum tsunami (PMT) at the site. Sources of tsunamis researched included a subduction zone event in the Hispaniola Trench, a volcanic cone collapse in the Canary Islands, and a Currituck landslide event on the continental shelf margin.

The licensee conducted the tsunami analysis using the numerical model FUNWAVE-TVD (Fully Nonlinear Wave-Total Variation Diminishing Scheme), with appropriate referencing. Specific information regarding bathymetry sources and grid development is provided in the FHRR. Recent and appropriate data sources are utilized (Kennedy et al., 2000; Shi et al, 2012; Kirby et al, 2013). The FHRR states that the PMT arises from the distant Canary Islands cone collapse with a maximum flood elevation of approximately 5.5 to 5.7 ft (1.69 to 1.74m) NAVD88. The licensee states that the site elevation is 26.5 ft (8.08 m) NAVD88 and the tsunami would not inundate the SPS site (Dominion, 2015). The licensee also analyzed other near- and far-field tsunamigenic sources potential for generating flood hazards at the Surry site. For the tsunami resulting from the Currituck landslide, the maximum predicted water levels near the SPS site ranged from 4.4 to 4.8 ft (1.33 to 1.45 m) NAVD88.

The staff reviewed the methodologies used by the licensee to determine the severity of the tsunami phenomena reflected in this analysis, and the staff noted that they are consistent with present-day methodologies and guidance. In the context of the above discussion, the staff finds the licensee's analysis and use of these methodologies is acceptable.

The staff conducted an independent confirmatory analysis to determine the PMT at the SPS site. The staff performed numerical modeling of three tsunami sources consisting of far-field seismogenic (Puerto Rico subduction zone), far-field (Canary Islands), and near-field (Currituck landslide) as potential generators for the PMT (ten Brink et al, 2008).

The staff used the Boussinesq-based numerical model COULWAVE (Lynett and Liu, 2002) for three different types of tsunami sources. For all conditions, the most conservative source parameters were employed, even when arguably unphysical, to provide an upper limit on the possible tsunami effects at the SPS site. The staff concludes that a Currituck-like landslide source is the PMT for the SPS site. The staff's maximum near-site tsunami water level was determined to be 12.1 ft (3.69 m) NAVD88, including the antecedent water level (10 percent high tide and 100-year sea level rise) of 6.9 ft (2.10 m) NAVD88. The staff note that source of the licensee's PMT (Canary Island cone collapse) differs from the PMT source identified by staff.

The staff reviewed the licensee's description within the FHHR, which provided results from a numerical simulation of a large landslide offshore of the SPS site (Dominion, 2015). The staff's assessment of the licensee's source was that it was similar in geometry to the NRC staff Currituck slide, but placed closer to the site. Note that the NRC staff analysis is a conservative estimate, with the largest source of conservatism arising from the assumption of a rapidly moving, entirely coherent landslide failure. The maximum water elevation of 12.1 ft (3.69 m) NAVD88 represents an upper limit on a possible tsunami from any plausible source; the average site elevation for the SPS site is 26.5 ft (8.08 m) NAVD88.

In summary, the NRC staff confirmed the licensee's conclusion that the flood hazard from tsunami alone could not inundate the site. The NRC staff confirmed that the reevaluated hazard for flooding from tsunami is bounded by the CDB flood hazard. Therefore, the NRC staff determined that the tsunami flood-causing mechanism does not need to be analyzed in a focused evaluation or an additional assessment consistent with the process and guidance discussed in COMSECY-15-0019 (NRC, 2015).

3.8 Ice-Induced Flooding

The licensee reported in its FHRR that the reevaluated flood hazard, including associated effects, for ice-induced flooding is based on a stillwater-surface elevation of 18.0 ft (5.49 m) MSL. Including wind waves and runup results in an elevation of 19.0 ft (5.79 m) MSL (Dominion, 2015). This flood-causing mechanism is not discussed in the licensee's CDB. The licensee reported in its FHRR that temperature data indicates infrequent, but possible temperatures below freezing (Dominion, 2015). The licensee also reported in its FHRR that historical records obtained from the USACE ice jam database (USACE, 2012) indicate that the largest ice jam of 18.0 ft (5.49 m) was observed near Richmond, Virginia in 1936.

The licensee followed the HHA approach and superimposed the historical ice jam of 18.0 ft (5.49 m) on top of the normal flow water level of James River, which has a mean tidal range of 1.0 ft (0.30 m) at SPS. The licensee then calculated the freeboard available in relation to the SPS plant grade level.

The maximum water surface elevation was calculated to be the sum of the ice jam and the tidal range at SPS resulting in 19 ft.0 ft (5.79 m) MSL (Dominion, 2015). The SPS site grade is at 26.5 ft (8.08 m) MSL; therefore, there is a freeboard of 7.5 ft (2.29 m). As a result of the available freeboard, the licensee excluded ice-induced flooding from further consideration. The staff confirmed the licensee's conclusion that the reevaluated hazard from ice-induced flooding is lower than the site grade. Therefore, the NRC staff determined that ice-induced flooding does not need to be analyzed in a focused evaluation or an additional assessment consistent with the process and guidance discussed in COMSECY-15-0019 (NRC, 2015).

3.9 Channel Migrations or Diversions

The licensee reported in its FHRR that the reevaluated hazard, including associated effects, for channel migrations or diversions does not inundate the plant site, but did not report a flood elevation. This flood-causing mechanism is not discussed in the licensee's CDB (Dominion, 2015).

The licensee reported that the James River is a maintained navigable waterway that has not exhibited a tendency to meander towards the SPS site. The licensee also reported that much of the critical shoreline at SPS is composed of strong and stable soil with moderate to high shear strengths. Therefore, based on the embankment properties and history of the river, channel migration is not a likely flooding mechanism at the SPS site (Dominion, 2015).

The NRC staff reviewed the information provided by the licensee and confirms the licensee's conclusion that the flood hazard from channel migrations or diversions is not a plausible flooding mechanism at SPS. Therefore, flooding from channel migrations or diversions does not need to be analyzed in a focused evaluation or a revised integrated assessment as discussed in COMSECY-15-0019 (NRC, 2015a) and associated guidance.

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

4.1 Reevaluated Flood Height for Hazards Not Bounded by the CDB

Section 3 of this staff assessment documents the staff's review of the licensee's flood hazard water elevations results. Table 4.1-1 contains the maximum results, including waves and runup, for flood mechanisms not bounded by the CDB presented in Table 3.1-2. The staff agrees with the licensee's conclusion that the LIP, onsite structure failure of the intake canal, and deterministic PMSS with James River 25-year flood hazard mechanisms are not bounded by the CDB. Consistent with the process and guidance discussed in COMSECY-15-0019 (NRC, 2015), the NRC staff anticipates that the licensee will submit a focused evaluation or additional assessment for these flood-causing mechanisms.

4.2 Flood Event Duration for Hazards Not Bounded by the CDB

The NRC staff reviewed information provided in the Dominion's 50.54(f) responses (Dominion, 2015 and NRC, 2016d) regarding the FED parameters needed to perform the additional assessments of plant response for flood hazards not bounded by the CDB.

The licensee provided a discussion of duration for the LIP flood-causing mechanism (Dominion, 2015). However the FHRR did not provide any discussion on the warning time or time for water to recede from the site.

The FHRR provided a discussion of warning time for failure of dams and onsite water control/storage structures (Dominion, 2015). However, the FHRR did not discuss duration or time for water to recede from the site.

The licensee did not provide in its FHRR a direct statement regarding the storm surge duration at the SPS site. The licensee provided a stage hydrograph for the third combined event alternative estimated at the SPS intake and discharge from which some duration information can be inferred. The hydrographs presented by the licensee in the FHRR only include surge combined with wave setup.

The licensee is expected to develop any missing FED parameters for the LIP, onsite structure failure of the intake canal, and deterministic PMSS with James River 25-year flood flood-causing mechanisms to conduct the MSA and the focused evaluations or revised integrated assessments as discussed in NEI 12-06 (Revision 2), Appendix G (NEI, 2015), and outlined in COMSECY-15-0019 (NRC, 2015) and associated guidance.

4.3 Associated Effects for Hazards Not Bounded by the CDB

The NRC staff reviewed information provided in the SPS 50.54(f) responses (Dominion, 2015 and NRC, 2016d) regarding the associated effects (AE) parameters needed to perform the additional assessments of plant response for flood hazards not bounded by the CDB.

The FHRR provided water velocities and maximum water depths, but does not discuss hydrodynamic loading for the LIP flood-causing mechanism (Dominion, 2015). Additionally, the licensee did not discuss AE for failure of dams and onsite water control/storage structures.

The licensee provided discussion of AE as a result of precipitation events, including wave effects and the deterministic PMSS with James River 25-year flood hazard mechanism. The licensee discussed the hydrostatic, hydrodynamic, and wave forces at the SPS intake under two scenarios. These scenarios considered were: 1) the controlling combined effects flood due to precipitation and waves effects, and 2) controlling combined effects flood including deterministic surge, river flooding, and wave effects along the SPS shorelines. The licensee used a conservative approach in the estimation of velocities from the most critical direction relative to the SPS site for the purpose of calculating the hydrodynamic and impact loading. The licensee computed hydrostatic forces at the SPS emergency service water pump and oil storage room. The licensee determined a maximum hydrostatic force of 4644 lb/ft (67.77 kN/m) at this location. The licensee determined the maximum flow velocity of 19.8 ft/s (6.04 m/s) and the maximum hydrodynamic load of 5798 lb/ft with resultant acting at a centroid with an elevation of 16.7 ft (5.09 m) NAVD88. The licensee determined a maximum breaking wave load for SPS Intake vertical walls of 58,048 lb/ft (847.1 kN/m). The maximum loadings were associated with the second scenario. The licensee stated that the hydrostatic and hydrodynamic loadings were "extremely conservative" and would be "subject to individual assessment during the integrated assessment" (Dominion, 2015).

The licensee provided discussion of debris loads as a result of precipitation events, including wave effects and the deterministic PMSS with James River 25-year flood hazard mechanism. These scenarios considered were: 1) the controlling combined effects flood due to precipitation and wave effects, and 2) controlling combined effects flood including deterministic surge, river flooding, and wave effects along the SPS shorelines. The maximum debris impact load at the SPS Emergency Service Water Pump and Oil Storage Room was 31,680 lbs (140.9 kN), which was associated with the second scenario based on a 2,000-lb (8.896 kN) debris weight. The licensee did not describe the formula coefficient used. The licensee stated that the debris loadings were "extremely conservative" and would be "subject to individual assessment during the integrated assessment" (Dominion, 2015).

The staff reviewed the force and loading calculations based on information provided in the FHRR. The staff were not able to verify the water and ground elevations used by the licensee to make the calculations (Taylor Engineering, 2015). Instead, the staff noted that the licensee's calculations were based on freshwater density which would not be as conservative as if the calculations were based on more dense seawater or a mixture of both fresh and sea water. The staff determined that the loadings would be a few percent higher if freshwater was not assumed. The staff determined that this difference was not significant considering the other uncertainties in the calculation. The staff were able to verify the loading calculation using staff's confirmed upper bound velocities and the licensee's flow depth information. The staff were not able to verify the drag coefficient used by the licensee in their force and loading calculations. However, the staff were able determine that a minimum drag coefficient value of 1.25, which is suitable for buildings with a width-to-height ratio of no greater than 12, would be consistent with the licensee's evaluation of the loading. The staff were able to verify that the licensee selection of the dynamic pressure coefficient was consistent with the highest Risk Category IV and the breaking wave loads estimated by the licensee. This was consistent with the ASCE 7-10, 5.4.4.2 and FEMA P-55, 8.5.8.2 formulas that the licensee referenced. The staff were not able to verify the licensee non-breaking wave load estimates because the FHRR does not provide the input conditions of results. The staff anticipates that the individual assessments of the loadings will be fully described in the integrated assessment as noted in the FHRR (Dominion, 2015).

The staff independently computed debris loads, which were found to be reasonably consistent (within 8 percent of the licensee's estimates), and therefore concluded that the licensee's debris load estimates were reasonably conservative.

The licensee stated In FHRR Section 2.9.2 that associated effects were "based on generalized extreme approximations (extremely conservative) and are subject to individual assessment during the integrated assessment."

The licensee is expected to develop any missing AE parameters for the LIP, onsite structure failure of the intake canal, and deterministic PMSS with James River 25-year flood flood-causing mechanisms to conduct the MSA and the focused evaluations or revised integrated assessments as discussed in NEI 12-06 (Revision 2), Appendix G (NEI, 2015), and outlined in COMSECY-15-0019 (NRC, 2015) and associated guidance.

4.4 Conclusion

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

The licensee is expected to develop FED parameters and applicable flood AEs to conduct the MSA as discussed in the NEI 12-06 (Revision 2), Appendix G (NEI, 2015a) and associated guidance.

5.0 CONCLUSION

The NRC staff has reviewed the information provided for the reevaluated flood-causing mechanisms of Surry Power Station, Unit Nos. 1 and 2. Based on its review of available information provided in Dominion's 50.54(f) response (Dominion, 2015 and NRC, 2016d), the staff concludes that the licensee conducted the hazard reevaluation using present-day methodologies and regulatory guidance used by the NRC staff in connection with ESP and COL reviews.

Based upon the preceding analysis, the NRC staff confirmed that the licensee responded appropriately to Enclosure 2, Required Response 2, of the 50.54(f) letter, dated March 12, 2012.

In reaching this determination, staff confirmed the licensee's conclusions that (a) the reevaluated flood hazard results for LIP, onsite structure failure of the intake canal, and deterministic PMSS with James River 25-year flood are not bounded by the current design-basis flood hazard; (b) additional assessments of plant response will be performed for these 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, 2015), JLD-ISG-2012-01, Revision 1 (NRC, 2016a), and JLD-ISG-2016-01, Revision 0 (NRC, 2016c). The NRC staff has no additional information needs at this time with respect to Dominion's 50.54(f) response for SPS.

6.0 REFERENCES

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

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

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

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

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

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

Reevaluated Flood-Causing Mechanisms and Associated Effects that May Exceed the Powerblock Elevation (26.5 ft MSL)[1]	ELEVATION (MSL)
Local Intense Precipitation and Associated Drainage	29.4 ft (8.9 m)
Failure of Dams and Onsite Water Control/Storage Structures	28.1 ft[2] (8.6 m)
Storm Surge	38.8 ft[3] (11.8 m)

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

[2] Onsite Structure Failure (Intake Canal).

[3] Deterministic PMSS with James River 25-year flood, East Side of Plant, Low Level Intake Structure.

Table 3.1-1. Summary of Datum Conversions for Surry Power Station (all values in ft)

	To		
From	**MSL**	**NAVD88**	**NGVD29**
MSL	0	-1.44	-0.54
NAVD88	+1.44	0	+0.9
NGVD29	+0.54	-0.9	0

Table 3.1-2. Current Design Basis Flood Hazards for SPS Site (Dominion, 2015)

Mechanism	Stillwater Elevation	Waves/ Runup	Design Basis Hazard Elevation	Reference
Local Intense Precipitation	Not included in DB	Not included in DB	Not Included in DB	FHRR Table 3.0-1
Streams and Rivers	No Impact on the Site Identified	No Impact on the Site Identified	No Impact on the Site Identified	FHRR Table 3.0-1
Failure of Dams and Onsite Water Control/Storage Structures	No Impact on the Site Identified	No Impact on the Site Identified	No Impact on the Site Identified	FHRR Table 3.0-1
Storm Surge				
PMH Flooding West Side	22.7 ft MSL	1.3 ft	24.0 ft MSL	FHRR Section 3.9
PMH Flooding East Side	22.7 ft MSL	5.9 ft	28.6 ft MSL	FHRR Section 3.9
Seiche	No Impact on the Site Identified	No Impact on the Site Identified	No Impact on the Site Identified	FHRR Table 3.0-1
Tsunami	No Impact on the Site Identified	No Impact on the Site Identified	No Impact on the Site Identified	FHRR Table 3.0-1
Ice-Induced Flooding	Not included in DB	Not included in DB	Not included in DB	FHRR Table 3.0-1
Channel Migrations/Diversions	Not included in DB	Not included in DB	Not included in DB	FHRR Table 3.0-1

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

Table 4.1-1. Reevaluated Hazard Elevations for Flood-Causing Mechanisms Not Bounded by SPS's CDB

Mechanism	Stillwater Elevation	Waves/ Runup	Reevaluated Hazard Elevation	Reference
Local Intense Precipitation Site-specific PMP	29.4 ft MSL	Minimal	29.4 ft MSL	FHRR Table 3.0-1 and Section 2.1.4
Failure of Dams and Onsite Water Control/Storage Structures Onsite Structure Failure (Intake Canal)	[redacted]	[redacted]	[redacted]	FHRR Table 3.0-1
Storm Surge Deterministic PMSS with James River 25-year Flood, East Side of Plant, Lower Level Intake Structure	24.2 ft MSL	14.6 ft	38.8 ft MSL	FHRR Section 2.9-7
Deterministic PMSS with James River 25-year Flood, West Side of Plant	24.2 ft MSL	Minimal	24.2 ft MSL	FHRR Table 2.9-4, FHRR Section 2.9.2.2, and FHRR Section 2.9.1.1

Note 1: Reevaluated hazard mechanisms bounded by the current design basis (see Table 3.1-2) are not included in this table

Note 3: Reported values are rounded to the nearest one-tenth of a foot.

Note 4: Onsite structure failure flood causing mechanism elevations are reported as the highest elevations at specific door locations.

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

Flood-Causing Mechanism	Time Available for Preparation for Flood Event	Duration of Inundation of Site	Time for Water to Recede from Site
Local Intense Precipitation and Associated Drainage	Not discussed	"Peak flood heights reduce significantly in 1 h with a considerably lower height for an 8-h or longer period." (FHRR Sec. 4.1)	Not Provided
Failure of Dams and Onsite Water Control/Storage Structures	"Little warning time" (FHRR, Sec. 4.3); estimated failure time for sunny-day failure is 0.5 h (FHRR, Sec. 2.3)	Not Provided	Not Provided
Storm Surge	Not Provided	Not Provided	Not Provided

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

	Flooding Mechanism		
Associated Effects Factor	**Local Intense Precipitation**	**Storm Surge[2,]**	**Failure of Dams and Onsite Water Control/Storage Structures[1]**
Hydrodynamic loading at plant grade	Minimal; maximum water depth 2.9 ft (0.9 m); maximum water velocity 5.0 ft/s (1.5 m/s) (FHRR, Sec. 2.1)	5798 lb/ft (84615.4 N/m)(at Emergency Service Water Pump and Oil Storage Room) and 58,046 lb/ft (847117.5 N/m) (wave load at SPS intake)	Not discussed, maximum water velocity is listed as 4.4 ft/s at 1-BS-DR-67 (Door 35)
Debris loading at plant grade	Unlikely (FHRR, Sec. 2.1)	31,680 lbs (14369.8 kg)	Not discussed
Sediment loading at plant grade	Not discussed	Not discussed	Not discussed
Sediment deposition and erosion	Not discussed	Not discussed	Not discussed
Concurrent conditions, including adverse weather	Not discussed	Not discussed	Not discussed
Other pertinent factors (e.g., waterborne projectiles)	Not discussed	Not discussed	Not discussed

N/A = Not applicable

[1] Flood hazard from failure of onsite water control or storage structures is similar in kind to the flood hazard from local intense precipitation, so these associated effects would be similar.

[2] The licensee stated in the FHRR Section 2.9.2 that associated effects (including hydrostatic, hydrodynamic, debris impact, and wave loads) "are based on generalized extreme approximations (extremely conservative) and are subject to individual assessment during the integrated assessment."

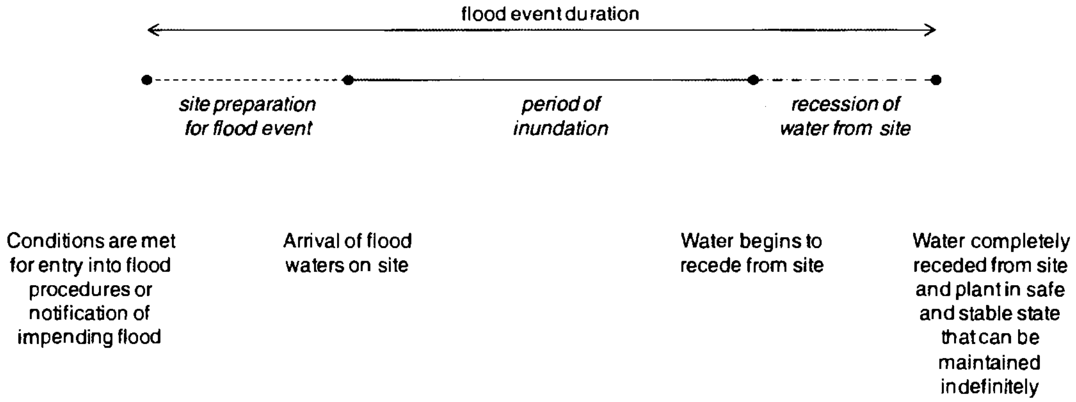

Figure 2.2-1. Flood Event Duration (NRC, 2012c)

Figure 3.1-1. Map of Surry Power Station site and vicinity. (Source: Dominion 2015a, Figure 1.1-1.)

Figure 3.1-2. Surry Power Station and the lower James River. (Source: NRC, 2016d).

Figure 3.1-3. Layout of the SPS site, including major structures and Intake and Discharge Canals. The Settling Pond is the notched rectangle directly east of the east end of the Discharge Canal. (Source: Dominion 2015a, Figure 1.1-2).

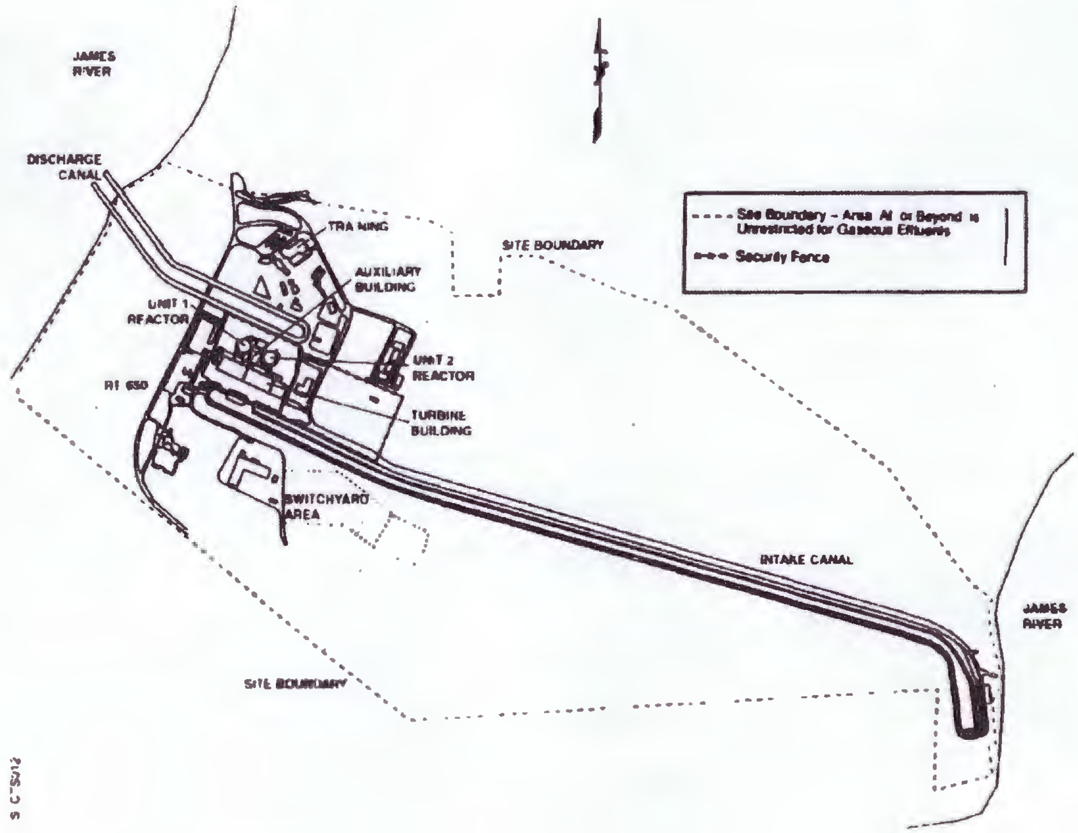

Figure 3.3-1. Delineation of James River watershed and subwatersheds. Subbasin 1 is Upper James River watershed, Subbasin 2 is Appomattox River watershed, and Subbasin 3 is Lower James River watershed. (Source: Dominion, Calculation No. 13-011, Figure 3.)

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

Sincerely,

/RA/

Lauren K. Gibson, Project Manager
Hazards Management Branch
Japan Lessons-Learned Division
Office of Nuclear reactor Regulation

Docket Nos. 50-280 and 50-281

Enclosures:
1. Staff Assessment of Flood Hazard Reevaluation Report (non-public, security-related information)
2. Staff Assessment of Flood Hazard Reevaluation Report (public)

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