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

September 30, 2016

Mr. Kelvin Henderson
Site Vice President
Duke Carolinas, LLC
Catawba Nuclear Station
4800 Concord Road
York, SC 29745

SUBJECT: CATAWBA NUCLEAR STATION, UNITS 1 AND 2 – STAFF ASSESSMENT OF RESPONSE TO 10 CFR 50.54(f) INFORMATION REQUEST – FLOOD-CAUSING MECHANISM REEVALUATION (CAC NOS. MF3625 AND MF3626)

Dear Mr. Henderson:

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, 2014 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML14077A054), Duke Carolinas, LLC (Duke, the licensee) responded to this request for Catawba Nuclear Station, Units 1 and 2.

By letter dated December 21, 2015 (ADAMS Accession No. ML15352A192), the NRC staff sent Duke a summary of the staff's review of the licensee's reevaluated flood-causing mechanisms. The enclosed staff assessment provides the documentation supporting the NRC staff's conclusions summarized in the letter. As stated in the letter, the reevaluated flood hazard results for several hazards were not bounded by the current design-basis flood hazard. Therefore, the NRC staff anticipates that the licensee will submit a focused evaluation or an integrated assessment as discussed in COMSECY-15-0019, "Closure Plan for the Reevaluation of Flooding Hazard for Operating Nuclear Power Plants," and JLD-ISG-2016-01, "Guidance for Activities Related to Near-Term Task Force Recommendation 2.1, Flooding Hazard Reevaluation; Focused Evaluation and Integrated Assessment". This closes out the NRC's efforts associated with CAC Nos. MF3625 AND MF3626.

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

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

Sincerely,

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

Docket Nos. 50-413 and 50-414

Enclosure:
Staff Assessment of Flood Hazard
Reevaluation Report

cc w/o encl: Distribution via Listserv

STAFF ASSESSMENT BY THE OFFICE OF NUCLEAR REACTOR REGULATION
RELATED TO FLOODING HAZARD REEVALUATION REPORT
NEAR-TERM TASK FORCE RECOMMENDATION 2.1
CATAWBA NUCLEAR STATION, UNITS 1 AND 2
DOCKET NOS. 50-413 AND 50-414

1.0 INTRODUCTION

By letter dated March 12, 2012 (NRC, 2012a), the U.S. Nuclear Regulatory Commission (NRC) issued a request for information to all power reactor licensees and holders of construction permits in active or deferred status, pursuant to Title 10 of the *Code of Federal Regulations* (10 CFR), Section 50.54(f) "Conditions of licenses," (hereafter referred to as the "50.54(f) letter"). The request was issued in connection with implementing lessons learned from the 2011 accident at the Fukushima Dai-ichi nuclear power plant as documented in the NRC's Near-Term Task Force 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 against current NRC requirements and guidance. Subsequent staff requirements memoranda associated with SECY-11-0124 (NRC, 2011c) and SECY-11-0137 (NRC, 2011d) directed the NRC staff address this recommendation through 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 the Flooding Hazard Reevaluation Report (FHRR) deadlines for individual plants. On May 11, 2012, the staff issued its prioritization of the FHRRs (NRC, 2012c).

If the reevaluated hazard for a flood-causing mechanism is not "bounded" by the plant's current design-basis (CDB) flood hazard, then an additional assessment of plant response is necessary, as described in the 50.54(f) letter; COMSECY-15-0019, "Closure Plan for the Reevaluation of Flooding Hazard for Operating Nuclear Power Plants" (NRC, 2015c); JLD-ISG-2012-01, Revision 1, "Compliance with Order EA-12-049 Order to Modify Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events," (NRC, 2016a), and JLD-ISG-2016-01, Revision 0, "Guidance for Activities Related to Near-Term Task Force Recommendation 2.1, Flooding Hazard Reevaluation; Focused Evaluation and Integrated Assessment," (NRC, 2016c). The FHRR, responses to the associated requests for additional information (RAIs), and the audit summary report (Duke, 2014b; Duke, 2014c; Duke, 2014d; Duke, 2015; and NRC, 2016b) provide the flood hazard input necessary to complete this additional assessment consistent with the process outlined in COMSECY-15-0019 (NRC, 2015c), and associated guidance.

By letter dated March 12, 2014 (Duke, 2014b), Duke Carolinas, LLC (Duke, the licensee) provided its FHRR for Catawba Nuclear Station (Catawba, CNS), Units 1 and 2. The NRC staff issued RAIs to the licensee by emails dated June 6, 2014 (NRC, 2014a), and April 29, 2015 (NRC, 2015a). The licensee responded to the RAIs by letters dated July 7, 2014 (Duke, 2014c), and July 28, 2015 (Duke, 2015). The licensee stated in its FHRR that interim actions and procedures exist to ensure that the plant will be safe during a flood event, and that these interim actions and procedures will be reevaluated and updated as determined by a focused evaluation and/or an integrated assessment (Duke, 2014b).

The reevaluated flood hazard results for local intense precipitation (LIP) and associated site drainage, rivers and streams, and dam failure flood-causing mechanisms are not bounded by the plant's CDB hazard. Consistent with the process outlined in COMSECY-15-0019 and JLD-ISG-2016-01, Revision 0 (NRC, 2015c 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. Additionally, for the rivers and streams and dam failure flood-causing mechanisms, the NRC staff anticipates that the licensee will submit (1) a revised integrated assessment or (2) a focused evaluation, confirming the capability of existing flood protection or implementing new flood protection consistent with the process outlined in COMSECY-15-0019 (NRC, 2015c) and JLD-ISG-2016-01 (Revision 0) (NRC, 2016c).

On December 21, 2015, the NRC issued a revised Interim Staff Response (ISR) letter to the licensee (NRC, 2015d). 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, "Requirements for Mitigation Strategies for Beyond-Design-Basis External Events" (NRC, 2012b) and the additional assessments associated with Recommendation 2.1: Flooding. The ISR letter also made reference to this staff assessment, which documents the NRC staff's basis and conclusions. The flood hazard mechanism values presented in the December 21, 2015, ISR letter's enclosure have been revised in this staff assessment. Upon further review, the staff removed the standby nuclear service water pond (SNSWP) dam entry in Table 2 of the December 21, 2015 ISR letter enclosure under the streams and rivers because it was actually bounded by the CDB. This staff assessment updates the flood hazard mechanisms in Table 2 of the ISR letter that should be considered in the mitigating strategies assessment (MSA) and subsequent NTTF 2.1 flooding activities. This staff assessment supersedes the December 21, 2015 ISR letter (NRC, 2015d). The NRC staff does not expect that this revision to Table 2 will have any impact on the licensee.

As mentioned in the ISR letter and discussed below, 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) and associated effects (AE) parameters to conduct the mitigating strategies assessment (MSA) as discussed in Revision 2 of NEI-12-06, Appendix G and JLD-ISG-2012-01, Revision 1, "Compliance with Order EA-12-049 Order to Modify Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events," (NRC, 2016a). These documents provide an approach for the development, implementation, and maintenance of mitigating strategies for flood hazards events exceeding their design basis. Appendix G of NEI-12-06 (NEI, 2015) provides guidance for conducting the MSA, which includes (1) characterizing the Mitigating Strategy Flood Hazard Information (MSFHI), (2) determining if the MSFHI is bounded by diverse and flexible coping strategies (FLEX), (3) evaluating flood-hazard impacts if the MSFHI is not bounded, and (4) demonstrating the robustness of flood protection and mitigation features. Duke will develop the FED parameters (warning times, period of inundation, and recession times) that were not provided as part of the FHRR review, which the staff will evaluate during its review of the MSA.

2.0 REGULATORY BACKGROUND

2.1 Applicable Regulatory Requirements

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 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. This section of the staff assessment describes present-day regulatory requirements that are applicable to the FHRR.

Sections 50.34 (a)(1), (a)(3), (a)(4), (b)(1), (b)(2), and (b)(4), of 10 CFR, describe the required content of the preliminary and final safety analysis 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 the loss of capability to perform their intended safety functions. The design bases for these SSCs are to reflect appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area. The design bases are also to have sufficient margin to account for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

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

The 50.54(f) letter requests all power reactor licensees and construction permit holders to reevaluate all external flooding-causing mechanisms at each site (NRC, 2012a). This includes current techniques, software, and methods used in present-day methodologies and guidance used by NRC for ESP and COL reviews.

2.2.1 Flood-Causing Mechanisms

Enclosure 2 of the 50.54(f) letter discusses flood-causing mechanisms for the licensee to address in the FHRR (NRC, 2012a). Table 2.2-1 lists the flood-causing mechanisms that the licensee should consider, and 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. JLD-ISG-2012-05, "Guidance for Performing the Integrated Assessment for External Flooding" (NRC, 2012d), defines "flood height and associated effects" as the maximum stillwater surface elevation plus:

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

2.2.3 Combined Effects Flood

The worst flooding at a site that may result from a reasonable combination of individual flooding mechanisms is sometimes referred to as a "combined 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" (for the purposes of this staff assessment, the terms "combined effects" and "combined events" are synonyms) as defined in American National Standards Institute/American Nuclear Society (ANSI/ANS) 2.8-1992 (ANSI/ANS, 1992) as follows:

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

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

2.2.4 Flood Event Duration

Flood event duration was defined in JLD-ISG-2012-05 (NRC, 2012d) 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 elevation is not bounded by the CDB flood elevation for any flood-causing mechanisms, the 50.54(f) letter (NRC, 2012a) requests licensees and construction permit holders to

- Submit an interim action plan with the FHRR documenting actions planned or already taken to address the reevaluated hazard.
- Perform an integrated assessment to: (a) evaluate the effectiveness of the CDB (i.e., flood protection and mitigation systems); (b) identify plant-specific vulnerabilities; and (c) assess the effectiveness of existing or planned systems and procedures for protecting against and mitigating consequences of flooding for the flood event duration.

If the reevaluated flood hazard is bounded by the CDB flood hazard for all flood-causing mechanisms at the site, licensees are not required to perform an integrated assessment. COMSECY-15-0019 and JLD-ISG-2016-01, Revision 0, outline a revised process for addressing cases in which the reevaluated flood hazard is not bounded by the plant's CDB (NRC, 2015c and NRC, 2016c). The revised process describes an approach in which licensees with LIP hazards exceeding their CDB flood will not be required to complete an integrated assessment, but instead will perform a focused evaluation that 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 CDB, licensees can assess the impact of these reevaluated hazards on their site by performing either a focused evaluation or an integrated assessment (NRC, 2015c and NRC, 2016c).

3.0 TECHNICAL EVALUATION

The NRC staff reviewed the information provided for the flood hazard reevaluation of Catawba, 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.

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

3.1 Site Information

The 50.54(f) letter (NRC, 2012a) includes the SSCs important to safety (e.g, the ultimate heat sink) in the scope of the hazard reevaluation. The licensee included this pertinent data concerning these SSCs in the FHRR (Duke, 2014b). The staff reviewed and summarized this information in the sections below.

3.1.1 Detailed Site Information

The Catawba Units 1 and 2 FHRR described the site-specific information related to the flood hazard reevaluation. The licensee used mean sea level (MSL) for elevations in the FHRR which were based on National Geodetic Vertical Datum 1929 (Duke, 2014b). All elevations in this staff assessment are in MSL.

The Catawba site, is located in northeastern York County, South Carolina, approximately 6 miles (mi) (9.7 kilometers (km)) north of Rock Hill, South Carolina. The site occupies a 0.61 mi^2 (1.58-km^2) tract on a peninsula of Lake Wylie, an impoundment of the Catawba River. It is bordered on the north by the embayment of Beaver Dam Creek and on the south by the embayment of Big Allison Creek. The main channel of Lake Wylie is located to the east of the Catawba site. Lake Wylie was originally created in 1904 with the construction of a small low head dam on the Catawba River for hydroelectric power production, and was enlarged to its current size in 1925 with the construction of Wylie Dam. The lake extends 28 mi (45 km) up the Catawba River north from Wylie Dam to Mountain Island dam. The impoundment also extends approximately 5 mi (8 km) up the South Fork, a western tributary that runs parallel to the Catawba River. The Wylie Dam and its hydroelectric station are approximately 4.8 river miles southeast of the Catawba site. Lake Wylie has a watershed area of approximately 3,020 mi^2 (7,820 km^2). At its full pond elevation of 569.40 feet (ft); (173.55 meters (m) MSL, it has a surface area of approximately 19.5 mi^2 (50.4 km^2), a shoreline of about 325 mi (523 km), a volume of 281,900 acre-ft (0.35 km^3), and a mean depth of 22.5 ft (6.86 m) (Duke, 2014b).

The plant grade at the powerblock (also referred to as "the yard") is at elevation 593.5 ft (180.90 m) MSL (Duke, 2014b). The mezzanine floor in the turbine, auxiliary, and service buildings and all exterior accesses to these buildings are at elevation 594.0 ft (181.1 m) MSL. The standby nuclear service water pond (SNSWP) is in the Beaver dam Creek embayment on the north side of the plant, formed by a dam across the embayment. The crest of the SNSWP dam is at elevation 595.0 ft (181.4 m) MSL (see Figure 3.1-1 of this staff assessment for site features). Table 3.1-1 provides the summary of the controlling reevaluated flood-causing mechanisms, including wind effect, wave, and runup, which the licensee computed to be higher than the powerblock elevation (Duke, 2014b).

3.1.2 Design-Basis Flood Hazards

The CDB flood levels are summarized by flood-causing mechanisms in Table 3.1-2 of this staff assessment. The licensee presented CDB flood level information in the FHRR Table 3-1 and clarified the information in response to RAIs (Duke, 2015) and during an audit with the NRC staff (NRC, 2015b). The licensee clarified that CDB flood levels for all hazards except LIP are based on the Updated Final Safety Analysis Report (UFSAR) of April 2012, while the October 2013 UFSAR contains more recent values for design basis flood levels for LIP (Duke, 2015). The NRC staff reviewed the information provided and determined that sufficient information was provided to be responsive to Enclosure 2 of the 50.54(f) letter (NRC, 2012a).

3.1.3 Flood-Related Changes to the Licensing Basis

As a result of the flood walkdown that was requested in the 50.54(f) letter, the licensee reported the various licensing basis flood-related and flood protection changes from the UFSAR in the FHRR Section 1.3 (Duke, 2014b). The NRC staff reviewed the information provided in the FHRR and determined that sufficient information was provided to be responsive to Enclosure 2 of the 50.54(f) letter.

3.1.4 Changes to the Watershed and Local Area

Section 1.4 of the FHRR, identifies changes to the local site topography and buildings since original construction. Section 1.4 (Duke, 2014b) also notes that changes in the Catawba River drainage basin have occurred since the initial licensing basis analyses for the Catawba, Units 1 and 2 were performed in 1970. The main change occurred in the Charlotte, North Carolina, area and in the areas surrounding the reservoirs where populations have increased. The licensee stated that the impacts of these changes are considered small percentages of the total drainage area. However, the licensee incorporated these changes in the reevaluation of hydrology as discussed in FHRR.

3.1.5 Current Licensing Basis Flood Protection and Pertinent Flood Mitigation Features

In the FHRR, Section 1.5 discusses a number of flood protection features implemented at Catawba, Units 1 and 2 (Duke, 2014b). The NRC staff reviewed the information provided in the FHRR and determined that sufficient information was provided to be responsive to Enclosure 2 of the 50.54(f) letter.

3.1.6 Additional Site Details to Assess the Flood Hazard

The licensee provided electronic versions of the input and output files used for numerical modeling related to the analyses for all flood-causing mechanisms in the FHRR (Duke, 2014b). The licensee also provided light distance and ranging (LiDAR) data for the LIP analysis (Duke, 2014d).

3.1.7 Plant Walkdown Activities

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

By letter dated November 27, 2012 (Duke, 2012), Duke provided the Flooding Walkdown Report for Catawba, Units 1 and 2. The walkdown report was supplemented by RAI responses, dated February 12, 2014 (Duke, 2014a). The staff issued a staff assessment on June 11, 2014 (NRC, 2014b), which documented its review of the Flooding Walkdown Report and concluded that the licensee's implementation of the flooding walkdown methodology met the intent of the walkdown guidance.

3.2 Local Intense Precipitation and Associated Site Drainage

The licensee reported in its FHRR that the reevaluated flood hazard analysis for LIP and associated site drainage results in a stillwater surface elevation of 595.5 ft (181.51 m) MSL for Unit 1 and 595.6 ft (181.54 m) MSL for Unit 2 (Duke, 2014b). This flood-causing mechanism is discussed in the licensee's CDB and the CDB probable maximum flood (PMF) elevation for LIP and associated site drainage is based on a stillwater surface elevation of 594.9 ft (181.33 m) MSL for Unit 1 and 595.9 ft (181.63 m) MSL for Unit 2 (Duke, 2014b and Duke, 2015).

The licensee's analysis followed the guidance of NUREG/CR-7046 (NRC, 2011e) in defining the LIP scenario (Duke, 2015). The licensee's reevaluation of LIP is based on a probable maximum precipitation (PMP) of 18.9 in (48.0 cm) for a 1-hour (h) duration over a 1-mi^2 (3-km^2) area, obtained from Hydrometeorological Report No. 52 (HMR-52) National Oceanic and Atmospheric Administration (NOAA) (NOAA, 1982). The 1-h storm event was modeled as a front-loaded temporal distribution in 5-minute intervals, with 6.16 in (15.65 cm) of rain occurring in the first 5 minutes. The staff confirmed that the rainfall values for the 1-h duration PMP event and the peak 5-minute period during that event were based on a reasonable interpretation of HMR-52.

For its reevaluation of LIP effects, the licensee used Innovyze Infoworks Integrated Catchment Model (ICM), Version 3.0 software 2012 (Innovyze, 2012). The ICM is an integrated one- and two-dimensional (1-D and 2-D) hydrodynamic model for hydraulics and hydrology. The licensee stated that they obtained land surface elevations from site-specific aerial photography and 2010 LiDAR survey data (Duke, 2014b). Overland flow in the plant area and the contributing drainage area was modeled as a 2-D process, while roofs from buildings were modeled using the Storm Water Management Model incorporated in ICM as 1-D sub-catchments that discharge to the ground over roof edges (modeled as weirs) and through scuppers (modeled as sluice gates). Figure 3.2-1 shows the area included in the model. The total area of the 2-D model zone is about 1 mi^2 (2.6 km^2), with building roofs modeled as 1-D sub-catchments occupy about 0.04 mi^2 (0.11 km^2) (Duke, 2015). The staff reviewed the model input and output files and agrees with the results of the modeling.

The licensee clarified how the model boundaries affect flow (Duke, 2015 and NRC, 2016b). In the model, higher-elevation areas outside the site are separated from the site by moat-like ditches that form part of the vehicle barrier system and would function as flow boundaries. A sensitivity analysis conducted by the licensee found that LIP runoff from these offsite areas could result in water spilling onto the site from the vehicle barrier system, increasing peak water surface elevations at specific site locations by 0.06 ft (0.02 m) or less (NRC, 2016b). The staff reviewed the information provided and agrees with the licensee's assertion that these small increases would not affect the results of the licensee's LIP analysis.

The licensee assigned a curve number of 98 for roofs and values of Manning's roughness coefficient (n-value) that range from 0.01 for tent roofs to 0.03 for asphalt. The licensee determined parapet elevations from LiDAR data, while roof scuppers were assumed to have sills extending 6 in. (15 cm) above the roof elevation (Duke, 2014d). The staff noted that 6-in. (15-cm) sills could prevent water from reaching the ground. The licensee clarified that the sill extensions is consistent with observed site conditions (Duke, 2015).

To analyze overland flow, the licensee used a 2-D model represented by a mesh containing 297,977 triangular elements. Manning's n values were set at 0.03 for grass, 0.023 for gravel, 0.036 for rip rap, 0.013 for concrete and asphalt, 0.07 for shrubs, and 0.1 for trees. Anchored Jersey barriers, security fences, and entrance gates in the plant area were modeled as elevated polygons to block water flowing through them (Duke, 2014d). The staff reviewed and agrees with the Manning's n values used in the model.

Modeling of LIP effects in the SNSWP conservatively assumed no outflow from the pond's spillway. Maximum water surface elevations and hydrographs are provided for 21 representative locations in the vicinity of safety-related facilities and for 22 locations of exterior doors to buildings with identified SSCs (Duke, 2014d). Reported maximum water surface elevations in the Catawba powerblock area around the main complex and diesel generator buildings range up to 595.5 ft (181.51 m) MSL for Unit 1 and 595.6 ft (181.54 m) MSL for Unit 2, compared with elevations of 594.9 ft (181.33 m) MSL for Unit 1 and 595.9 ft (181.63 m) MSL for Unit 2 in the CDB (Duke, 2014b).

The staff confirmed that the licensee's reevaluation of the hazard from LIP and associated drainage used present-day methodologies and regulatory guidance. The staff also confirmed the licensee's conclusion that the reevaluated flood hazard for LIP and associated drainage for Unit 1 is 595.5 ft (181.51 m) MSL, which is not bounded by the CDB of 594.9 ft (181.33 m) MSL and for Unit 2 the reevaluated flood hazard elevation is 595.6 ft (181.54 m) MSL, which is bounded by the CDB of 595.9 ft (181.63 m) MSL. Therefore, the NRC staff expects that the licensee will submit a focused evaluation consistent with the process and guidance discussed in COMSECY-15-0019 (NRC, 2015c) and JLD-ISG-2016-01, Revision 0 (NRC, 2016c).

3.3 Streams and Rivers

The licensee reported in its FHRR that the reevaluated flood hazard analysis, for streams and rivers results in a stillwater surface elevation of 590.7 ft (180.05 m) MSL for Lake Wylie Catawba intake and [[ ]] for the SNSWP dam PMF (Duke, 2014b). Including elevation from wind, waves, and runup in the SNSWP dam PMF analysis results in an elevation of [[ ]] (Duke, 2014b). For Lake Wylie Catawba intake, the licensee did not include wind waves and runup in the reevaluated analysis because the intake area is protected by a cove from Lake Wylie.

The licensee provided a peak water surface elevation of [[ ]], which included wave runup, for the SNSWP dam PMF in Table 2.4.3.1 of the FHRR (Duke, 2014b). The staff notes that in FHRR Table 3-1 the licensee states a value for the stillwater surface of [[ ]] for the SNSWP dam PMF (Duke, 2014b). However, the staff calculated the stillwater surface elevation by subtracting the wave runup height of [[ ]] (as reported in FHRR Table 2.4.3-1) from the peak water surface elevation of [[ ]] to get [[ ]] for the stillwater surface elevation, which is the value listed in Table 4.1-1.

This flood-causing mechanism is discussed in the licensee's CDB. The CDB PMF elevation for streams and rivers is based on a stillwater surface elevation of [[ ]] for Lake Wylie Catawba intake and [[ ]] for the SNSWP dam PMF. With wind waves and runup the CDB for the SNSWP dam PMF is [[ ]] (Duke, 2014b). For Lake Wylie Catawba intake wind, waves, and runup were not analyzed in the CDB.

The licensee evaluated flooding in streams and rivers by simulating the passage of the PMF through each Duke dam and reservoir in the Catawba-Wateree Basin. The reevaluated model, herein known as the 2013 Catawba River Model, is based on several components from previous models used in the past. Figure 3.3-1 of this staff assessment depicts the model development history (Duke, 2104b). The FHRR (Duke, 2014b) states that the licensee's PMF reevaluation is based on the 1992 PMF evaluation performed as part of the Federal Energy Regulatory Commission (FERC) compliance activities. The PMF evaluation was performed using the HEC-1 (USACE, 1998) hydrologic model to develop rainfall-runoff hydrographs for the tributary watersheds and the DAMBRK hydraulic model (Fread, 1991) to route the PMF along the Catawba River. The model uses a regional Soil Conservation Service (SCS) unit hydrograph methodology (SCS, 1986) to simulate the runoff response for excess rainfall for the Catawba River sub-basins. The lag time is determined by varying the unit hydrograph lag time until the calculated sub-basin runoff hydrograph approximately coincides with the observed sub-basin gage hydrograph for each analyzed storm. The licensee tabulated lag times for each basin and storm event and calculated an average basin lag time (Duke, 2014b).

The licensee stated in its FHRR (Duke, 2014b) that they adopted the HEC-1 model to develop the inflow hydrographs for the 2013 Catawba River Model. They replaced the DAMBRK routing model with the Hydrologic Engineering Center - River Analysis System (HEC-RAS) Version 4.1 (USACE, 2010) model in order to determine maximum water surface elevations at Catawba, Units 1 and 2. The licensee used the DAMBRK model to establish the timing of the inflow hydrographs. To maintain consistency with the 1992 DAMBRK model, the licensee combined select inflow hydrographs and added additional tributary inflows. The licensee applied area proration to the sub-basin inflow hydrographs to distribute the flow within the modeled tributary reaches in the 2013 Catawba River Model, conserving the total inflow hydrograph for each respective sub-basin. The licensee made time adjustments to individual inflow hydrographs so that the superposition of the routed hydrograph reasonably matched the FERC approved 1992 PMF hydrographs for the Cowans Ford and Wylie subbasins.

The licensee extracted mainstream river and tributary reach cross sections, bank lines, flow paths, and main stream/tributary junctions from a geo-referenced digital terrain model (DTM) in HEC-RAS (Duke, 2014b).

The licensee indicated that the results are an adequate representation of the basin runoff response and thus no adjustment of the unit hydrographs was necessary to simulate the PMF events. The model used an operation methodology to enforce that flow is equivalent to outflow (Duke, 2014d). The staff confirmed, based on the review of the model input and output files, that the modified dam discharge parameters reflect physical site parameters that existed at the time of the August 1940 event in order to replicate as-existed conditions.

The licensee estimated the Catawba River PMP values using Hydrometeorological Report No. 51 (HMR-51) (NOAA, 1978) and HMR-52 (NOAA, 1982). The bounding PMP associated with the reevaluation is based on a 216 hour rainfall event composed of three 72 hour precipitation sub-events in sequence: the 40 percent PMP, 72 hours of zero rainfall, and the HMR-51 PMP. The licensee developed two sets of inflow hydrographs (216 hours) using the HEC-1 model for Cowans Ford Dam and Wylie Dam consistent with the respective sub-basins designated for each development during the 1992 and 1998 FERC PMF studies. Antecedent Moisture Conditions (AMC) 2, representing average soil moisture, were used in the simulation (Duke, 2014b). The licensee (Duke, 2015) noted that FERC accepted the PMF analysis using AMC 2 conditions and stated that it was not realistic to assume AMC 3 conditions in combination with modeling of the sequence of a 40 percent PMP event followed 72 hours later by a full PMP event. Additionally, the licensee stated that the AMC 2 condition is incorporated in its Catawba River Model; that the modeling of a 40 percent PMP event antecedent to the PMP provides for an antecedent moisture situation, and that this approach is consistent with NRC guidance and previously accepted modeling (NRC, 2016b).

Since most of the major dams on the Catawba River did not exist during the 1916 and 1940 storm events that were used in calibrating the river model, the licensee explained that unit hydrographs had been developed and used in the model to predict flow at the dams that existed at the time of the historical flooding events, and model predictions had been compared with available data on observed conditions during the historical events (Duke, 2015 and NRC, 2016b). The licensee also noted that the main emphasis had been on flows in the upper parts of the watershed. The staff confirmed that the described approach is consistent with current methods and is reasonable for the purposes of the 50.54(f) letter.

Based on the review of the input and output files, the licensee used the 2013 Catawba River Model to simulate the hydraulic performance for the Duke hydroelectric facilities (Duke, 2014b). Assumptions made for the HEC-RAS modeling of the PMF were:

- Setting starting reservoir elevations at reservoir target elevations established by the FERC operating license, which are below normal full pond elevations;
- Accounting for reduction in capacity due to sedimentation by using updated reservoir storage curves based on available bathymetry;
- Removing hydro plants from service when the flood tailwater elevation below each of the Duke Developments exceeds the substation yard elevation;
- Accounting for debris accumulation by reducing gated spillway discharge capacities by 5 percent at the Wylie Dam;
- Applying initial abstractions during the antecedent storm, and
- Applying the same 1992 DAMBRK model PMF hydrographs response at Cowans Ford Dam and Wylie Dam such that they are indicative of the 2013 basin hydraulic response to the PMF inflows.

The reevaluated hydraulic simulation of the PMF flood event included a HEC-RAS model of the 2013 Catawba-Wateree Watershed. The licensee modeled approximately 165 mi (265 km) of the Catawba River basin and performed unsteady HEC-RAS simulations with the verified model for the PMF evaluation (Duke, 2014b). The licensee indicated that all warning errors had been reviewed during the modeling process, and that the warnings that remained in the final model files had been found to be inconsequential to the simulation (Duke, 2015). The staff confirmed this approach as an appropriate application of engineering judgment.

During the review, the staff noted that the model cross sections at the plant site did not appear to cover the actual plant powerblock area and SNSWP dam (NRC, 2015a and NRC, 2016b), and the licensee clarified cross-section locations and interpretation of features, and explained that a decision had been made not to extend the cross sections from the 1-D model onto the areas on the plant site where 2-D modeling would be used to analyze water levels in detail (Duke, 2015 and NRC, 2016b). The licensee described this approach as conservative with respect to water levels, since part of the cross section for flow was not included in the 1-D model.

The staff reviewed the information provided by the licensee regarding the PMF analysis and confirms that the licensee's reevaluation of the hazard from flooding of streams and rivers uses present-day methodologies and regulatory guidance and the licensee's conclusion that the stillwater surface reevaluated hazard elevation of 590.7 ft (180.05 m) MSL for Lake Wylie Catawba intake is not bounded by the CDB stillwater surface elevation of 581.1 ft (177.12 m) MSL. For Lake Wylie Catawba intake the licensee did not include wind waves and runup in the analysis because the intake area is protected by a cove from Lake Wylie and the staff agrees with that approach. The SNSWP dam reevaluated elevation including wind waves and runup is [[ ]], which is bounded by the CDB of [[ ]]. Therefore, for the streams and rivers PMF at the Lake Wylie Catawba intake location, the NRC staff expects that the licensee will submit a focused evaluation for these hazards or an integrated assessment, consistent with the process and guidance discussed in COMSECY-15-0019 (NRC, 2015c) and JLD-ISG-2016-01, Revision 0 (NRC, 2016c).

3.4 Failure of Dams and Onsite Water Control/Storage Structures

The licensee reported in the FHRR that the reevaluated flood hazard analysis for failure of dams and onsite water control or storage structures results in a stillwater surface elevation of [[ ]] for the Lake Wylie Catawba intake and for the SNSWP dam. Including wind waves and runup results for the Lake Wylie Catawba intake and the SNSWP dam result in an elevation of [[ ]]. The reevaluated flood hazard analysis for failure of dams and onsite water control or storage structures results in a stillwater surface elevation of [[ ]] for Allison Creek Catawba Discharge. Wind wave runup is not applicable to this location. The licensee also considered the effects of cooling tower failure to the plant site (Duke, 2014b).

This flood-causing mechanism is discussed in the licensee's CDB. The CDB PMF elevation for failure of dams and onsite water control or storage structures is based on a stillwater surface elevation of 592.4 ft (180.56 m) MSL for Lake Wylie Catawba intake, SNSWP dam, and Allison Creek Catawba Discharge (Duke, 2014b). The corresponding flood elevations with wind wave runup at those three locations are 593.9 ft (181.02 m) MSL for Lake Wylie Catawba intake, 594.6 ft (181.23 m) MSL for SNSWP dam, and 593.6 ft (180.93 m) MSL for Allison Creek Catawba Discharge (Duke, 2014b).

3.4.1 Dam Failure Assumptions and Modeling

The licensee stated in the FHRR (Duke, 2014b) that there are a total of 11 hydroelectric reservoirs and 13 FERC-regulated hydroelectric dams and powerhouses along the Catawba River. Duke owns and operates the Wylie Dam and six other major reservoir developments upstream from Lake Wylie that regulate flows on the Catawba River. These upstream dams and their associated reservoirs are the Bridgewater development (including Paddy Creek, Linville, and Catawba dams) and Lake James; Rhodhiss Dam and Lake Rhodhiss; Oxford Dam and Lake Hickory; Lookout Shoals Dam and Lake; Cowans Ford Dam and Lake Norman; and Mountain Island Dam and Lake (Figure 3.4-1) (Duke, 2014b).

As a basis for the analysis of the flooding hazard from dam failure, the licensee conducted a screening process to identify the appropriate Catawba River basin dams to include in its analyses of dam failure effects at the Catawba site (Duke, 2014b). The licensee identified all Duke hydroelectric dams as critical dams due to their large storage capacity and locations. The licensee removed very small dams from consideration due to the low cumulative water-level increase (approximately 0.1 ft (0.03 m) in Lake Wylie). The licensee identified 12 major dams out of 262 upstream of the Catawba site applicable to the dam failure analysis. The staff confirmed that the licensee's dam screening approach is consistent with the Interim Staff Guidance JLD-ISG-2013-01 (NRC, 2013b) and therefore, agrees with the selection of dams that were analyzed.

As described in the FHRR, the evaluation of flooding at Catawba Units 1 and 2 due to upstream dam failure considered the consequences of flooding caused by fair-weather dam failure, seismic dam failure, and hydrologic dam failure induced by a PMF (Duke, 2014b). The licensee's results demonstrated that all of the Duke dams would [[.]]. Accordingly, [[ ]] is the bounding scenario for this flood hazard. The bounding design-basis flood for dam failure includes the Cowans Ford PMF, accompanied by overtopping failures of Oxford Dam, Lookout Shoals Dam, and the three Cowans Ford Dam structures, and the cascading failures of Mountain Island and Wylie Dams. The Cowans Ford PMF is a combination of the 40 percent of the 72-h PMP and a full 72-h PMP event over the Cowans Ford Dam drainage basin. The licensee developed overtopping breach parameters including width and time of breach for Bridgewater, Cowans Ford, Mountain Island, and Wylie Dams using regression methodologies for earth embankments (Duke, 2014b). The licensee reviewed several regression-based dam breach parameter equations, and then selected the Froehlich regression equation (Froehlich, 1995) for modeling. The earth dam breach parameters were used in the HEC-RAS model U. S. Army Corps of Engineers (USACE) (USACE, 2010). Overtopping failures were developed at Rhodhiss, Oxford, and Lookout Shoals Developments using existing FERC concrete dam structure stability analyses.

The licensee used results from PMF with non-failure to determine the PMF event that would be used for the final dam failure scenarios. Once a PMF event was selected, the licensee followed a sequential modeling simulation order to determine external dam failure flood impacts at the Catawba site due to this PMF event (Duke, 2014b). The licensee used the HEC-RAS model to simulate an unsteady flow due to dam failure based on 1-h time increments for inflow hydrographs, 1-minute computation intervals, 1-minute hydrograph output intervals, and 11-day total simulation time. The licensee assumed that all spillway gates at Oxford, Cowans Ford, and Wylie Dams were fully functional during the PMF event as required by FERC licensing conditions. The licensee modeled gated spillways as having a 5 percent capacity reduction due to debris. The licensee performed sensitivity runs to test dam failure outcomes relative to changes in Manning's n-values, the number of upstream dams involved in cascading failures, breach size, and failure time (Duke, 2014b).

The licensee's HEC-RAS simulation results (for model scenario "8j4," which is a bounding scenario among many postulated dam failure scenarios) indicate a peak water surface elevation of [[ ]] in Lake Wylie reservoir immediately adjoining the CNS intake, indicating a surcharge depth at the entrance to the CNS powerblock of [[ ]]. The licensee found that modeled water levels resulting from the dam failure scenario in Lake Wylie at the SNSWP dam [[ ]] crest elevation at model simulation [[ ]], leading to overtopping of the dam and subjecting the [[ ]] from water flowing over the dam. The licensee used standard equations for the design of riprap slopes to assess the stability of the upstream slope of the SNSWP dam against erosive effects of water overtopping the dam (NRC, 2016b).

The licensee also evaluated the potential for a subsequent rapid drawdown of Lake Wylie to threaten the stability of the SNSWP dam (Duke, 2014d), which is an earthen dam. The assumptions used in the most conservative rapid drawdown presented in the FHRR were:

(1) The water level in the SNSWP was assumed to be equal to the crest of the earthen fill at [[ ]],

(2) The water level in Lake Wylie was assumed to drop to its full pond elevation of [[ ]],

(3) The [[ ]] connecting the SNSWP with Lake Wylie was assumed to be insufficient to lower the pond water level, and

(4) The earthen fill forming the dam was assumed to be fully saturated. Material properties for the dam and the underlying soil and rock were estimated from a combination of design parameters in the UFSAR and related Duke documents, as-built information, and engineering judgment.

The licensee performed stability calculations using SLOPE/W software (GEO-SLOPE, 2012) to determine a minimum factor of safety of 1.99, which exceeds the minimum value of 1.1 required by FERC and USACE (FERC, 2006 and USACE, 2003). The staff noted that the failure of Wylie Dam could reduce the level of Lake Wylie. The licensee provided the result of a revised calculation (NRC, 2016b) to justify the assumption that the rapid drawdown of Lake Wylie following the overtopping of the SNSWP dam would lower the reservoir only to its full pond elevation and not to a lower elevation associated with the failure of Wylie Dam. For this new case included in the revised calculation (upstream water elevation of [[ ]] and downstream elevation of [[ ]], the licensee found a factor of safety of 1.90 for the critical failure surface in the dam, which exceeds the minimum value of 1.1 required by FERC and USACE (FERC, 2006 and USACE, 2003). The staff reviewed the licensee's modeling methods described above and concludes that the licensee's analyses used current methods, reasonable assumptions, and indicates a sufficient factor of safety.

3.4.2 Combined Events

The licensee included the effects of the combined dam failure scenario that included the effects of wind-wave runup on Lake Wylie generated by a 2-year wind speed applied in the critical direction and evaluated resulting water levels within the CNS powerblock area (Duke, 2014a).

The licensee used the ICM 2-D model (Innovyze, 2012) employed for the LIP evaluation to evaluate flooding effects in the CNS yard. The model domain was the same as used for the LIP analysis, except that flood hydrographs for Lake Wylie and Allison Creek generated by HEC-RAS were assigned as boundary conditions for the southern and eastern sides of the CNS site and the downstream side of the SNSWP dam. The licensee reported maximum model-predicted stillwater flood elevations in the CNS yard to be between [[ ]] around the main complex and between [[ ]] around the diesel generator buildings for Units 1 and 2, respectively.

The licensee also used Coastal Engineering Design and Analysis System, Automated Coastal Engineering Software (Leenknecht et al., 1992) to determine the generation of wind-driven waves and the numerical model COULWAVE (Lynett et al., 2002) to determine the effect of runup from wind-driven waves, based on equations found in the USACE Coastal Engineering Manual (USACE, 2003). The licensee computed the effect of wave runup based on the water depth and added it to the stillwater elevations predicted by the ICM model; wave runup increased the stillwater elevation by [[ ]] for all water depths of [[ ]] or more (Duke, 2014b). The staff noted that this represents the height of wave runup against the vertical walls of buildings. At the 22 exterior doors to buildings with identified SSCs, the analysis predicted maximum surface elevations of [[ ]] (Duke, 2014b).

The licensee explained that the initial reservoir water surface elevations used in the model are based on 33 years of historical operating records showing historical reservoir elevations, and noted that analysis of the data indicates that all reservoirs normally remain below their maximum pool levels (Duke, 2015). The licensee did not consider a sensitivity analysis for water levels, but due to the modeling of a 40 percent PMF antecedent storm, modeled water elevations in upstream reservoirs at the beginning of the PMF exceeded the normal FERC target elevations (except for Cowans Ford, where aggressive management of water levels after the antecedent storm would result in a water elevation 0.1 ft (0.03 m) below the normal target elevation) (Duke, 2015). The staff agrees that this approach is reasonable.

The licensee also explained that available dam stability information had been used in assessing seismic stability of the dams and supported the assumption that a seismic event would not result in an instantaneous failure of a concrete gravity dam or cause significant slope failure of an embankment dam beyond the available freeboard (Duke, 2015). The licensee stated that the 5 percent spillway reduction factor was deemed adequate due to the large width and height of the individual spillway gates and Duke's debris management program at all Catawba River reservoirs. The licensee explained that the assumed operation of hydropower turbines at all dams has negligible impact on hydraulic performance at those dams. For Cowans Ford Dam, where the turbines have greater significance, the model assumed that only three out of the four units were operating and that they stop operating above reservoir elevation 770 ft (234.7 m) MSL (Duke, 2015). The staff confirms the licensee's approach is reasonable.

Regarding breach parameters, the licensee's selected breach parameters were within the ranges of values predicted by the Froehlich empirical breach models (Duke, 2015). The licensee adjusted the parameters for breach geometry to be consistent with the physical conditions controlling the size and shape of a dam breach at each dam, and the selection of failure times had been informed by empirical predictions of breach flow. The licensee noted that the combination of parameters used in its modeling of the breach of the upstream Cowans Ford Dam resulted in a HEC-RAS-predicted total breach flow at the upper end of the confidence range of breach flow values predicted by the regression model for the main section of the dam (Duke, 2015). The licensee stated that the regression equations for dam breaches are not applicable to the concrete section of the Wylie Dam bulkhead, and that the modeled rapid failure of the Wylie Dam bulkhead concrete section following overtopping is reasonable because the [[ ]] section is an [[ ]] structure that would [[ ]] once the factor of safety was exceeded due to overtopping (NRC, 2016b). However, the left concrete bulkhead section is secured with tendon anchors and would not fail. Additionally, the licensee stated that the choice of a low-end value for the failure duration at the downstream Wylie Dam is justified by the rapid predicted rate of water-level rise [[ )]] at Wylie Dam vs. [[ )]] at Cowans Ford Dam) and greater flow velocity [[ )]] at Wylie Dam and [[ )]] at Cowans Ford Dam) predicted at Wylie Dam (NRC, 2016b). The staff agrees that the licensee's selections of breach parameters were consistent with JLD-ISG-2013-01 (NRC, 2013b) and were reasonable.

3.4.3 Cooling Tower Failure

The licensee presented in Section 2.8.3 of the FHRR an analysis of the flooding hazard resulting from failure of one of the six above-grade cooling towers located southeast of the powerhouse yard (Duke, 2014b). The analysis considered failure of the cooling tower nearest the powerblock and assumed it was full at the time of failure, containing 119,210 ft^3 (3,376 m^3) of water. The licensee simulated three scenarios with different breach widths, representing instantaneous breach of 11 percent, 22 percent, and 31 percent of the cooling tower circumference on the side facing the Catawba powerblock. The licensee used the ICM 2-D model (Innovyze, 2012) to simulate the effects of the breaches, with site drainage not functioning. Model results indicate that the released water would cause shallow ponding (at maximum depths of less than 2 ft (0.61 m) within the cooling tower yard. Some water would overtop the berm at the perimeter of the cooling tower yard and would reach the Catawba powerblock, inundating a small area at an average water depth of only 1 in. The breach width was found to have a negligible effect on the peak water depth (Duke, 2014b). The staff noted that the model-predicted water depths are consistent with applying the reported 119,210 ft^3 (3,376 m^3) water volume over the 1,411,000 ft^2 (131,000 m^2) area of the cooling tower yard, and confirms the licensee's conclusion that the flood hazard from failure of the cooling tower would not inundate the site.

3.4.4 Summary

The staff reviewed the flooding hazard from failure of dams and onsite water control or storage structures against the relevant regulatory criteria based on present-day methodologies and regulatory guidance and confirms 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 for the Lake Wylie Catawba intake, the SNSWP dam, and the Allison Creek Catawba discharge. Therefore, the NRC staff expects that the licensee will submit a focused evaluation for this hazard, or an integrated assessment consistent with the process and guidance discussed in COMSECY-15-0019 (NRC, 2015c) and JLD-ISG-2016-01, Revision 0 (NRC, 2016c).

3.5 Storm Surge

The licensee reported in its FHRR that the reevaluated flood hazard analysis for storm surge results in a stillwater surface elevation of 569.6 ft (173.61 m) MSL (Duke, 2014b). Including wind waves and runup results in an elevation of 575.9 ft (175.53 m) MSL. This flood-causing mechanism is discussed in the licensee's CDB. The CDB elevation for storm surge is based on a stillwater surface elevation of 569.4 ft (173.6 m) MSL. Including wind waves and runup, the CDB is 577.8 ft (176.11 m) MSL (Duke, 2014b).

The licensee stated in its FHRR that Lake Wylie is more than 150 mi (241 km) from the Atlantic Ocean and would not be subject to ocean-related storm surge or flooding. Additionally, the licensee stated that the storm-related pressure differential across Lake Wylie (a relatively small water body) would not be large enough to result in significant water surface variations to produce a storm surge (Duke, 2014b).

The licensee analyzed wind-wave generation on Lake Wylie from a 116-miles per hour (mi/h) (187 kilometers per hour (km/h)) wind occurring over the reservoir at its normal water elevation of 569.4 ft (173.55 m) MSL. The licensee selected the 116-mi/h (187 km/h) wind speed because it is the speed used in the licensing basis of the riprap design for the SNSWP dam and is assumed by the licensee to represent a hurricane wind speed. With this wind speed, the licensee calculated a maximum wave height of 4.3 ft (1.31 m) in Lake Wylie near the Catawba site. The licensee estimated a wave runup plus setup at the SNSWP dam of 2.2 ft (0.67 m), resulting in a maximum water surface elevation of 575.9 ft (175.53 m) MSL. Water surface elevations would be well below site grade and other elevations of possible concern and is below the CDB (with wind wave runup) of 577.8 ft (176.11 m) MSL (Duke, 2014b).

The staff reviewed the information provided by the licensee and confirms the licensee's conclusion that the reevaluated flood hazard for flooding from storm surge is bounded by the CDB. Therefore, flooding from storm surge does not need to be analyzed in a focused evaluation or an integrated assessment.

3.6 Seiche

The licensee did not evaluate seismically- or meteorologically-induced seiche, as it is minimal and will not inundate the plant site (Duke, 2014b). This flood-causing mechanism is discussed in the licensee's CDB as having no impact on the site (Duke, 2014b).

In Section 2.4.1 of the FHRR, the licensee calculated the reevaluated flood elevation by assuming a surge and seiche together with one mode of oscillation in a rectangular-shaped basin of constant depth (Duke, 2014b). Increasing modes of oscillation are less common and less threatening because the energy in these modes is dampened more rapidly. The length of the representative rectangular basin was chosen using engineering experience to consider the shape of the reservoir and potential seiches that may occur (Duke, 2014b). The surge and seiche reevaluation considered the effect of wind set-up. The licensee concluded that this flood-causing mechanism is bounded by the combined dam failure flooding discussed in Section 3.4 of this staff assessment (Duke, 2014b).

The staff reviewed the licensee's approach in evaluating the surge and seiche together and agrees with that approach. The staff confirms the licensee's conclusion that the reevaluated hazard for flooding from seiche is bounded by the maximum flood elevation for a combined dam failure event. Therefore, flooding from seiche does not need to be analyzed in a focused evaluation or a revised integrated assessment.

3.7 Tsunami

The licensee reported in the FHRR that the reevaluated hazard for tsunami does not inundate the plant site. This flood-causing mechanism is not discussed in the licensee's CDB because tsunamis were not postulated to impact the site (Duke, 2014b).

In the FHRR, Section 2.5 states that tsunami-induced flooding will not occur at the site because the plant site is not located on an open ocean coast or large body of water (Duke, 2014b). The licensee did not consider landslide tsunami flooding with its associated effects (e.g., wind waves, sediment) on Lake Wylie in the FHRR because based on a Geographical Information System (GIS) analysis around the Lake Wylie shoreline, the shoreline adjacent to the Catawba site was not considered to have the potential for producing landslides of the magnitude required to develop a seiche on the reservoir (Duke, 2015). The staff reviewed the results of the licensee's GIS analysis and found that the slopes on the Lake Wylie shoreline are mild (the maximum slope ratio is 2.4 horizontal and 1 vertical). Therefore, the staff concurs with the licensee that floods caused by Lake Wylie landslides are highly unlikely.

The staff confirms the licensee's conclusion that the reevaluated hazard for flooding from tsunami does not impact the plant site. Therefore, the flooding from tsunami does not need to be analyzed in a focused evaluation or an integrated assessment.

Ice-Induced Flooding

The licensee reported in its FHRR that the reevaluated hazard for ice-induced flooding does not inundate the plant's site. This flood-causing mechanism is not discussed in the licensee's CDB because ice-induced flooding was never postulated to impact the site (Duke, 2014b).

Section 2.6 of the FHRR stated that the Catawba site is not located in an area of the United States subjected to periods of extreme cold weather that have been reported to produce surface water ice formations (Duke, 2014b). The climate at the Catawba site is characterized by short, mild winters and long, humid summers. The licensee reported that local climatology data for Winthrop College near Rock Hill, South Carolina, for a period of December 1899 through March 2012 show an average annual minimum air temperature of 50.7 °Fahrenheit. The licensee reported that there has not been a recorded event of significant surface ice formation on Lake Wylie or Catawba River in the last 100 years (Duke, 2014b). The licensee noted that there are no recorded, ice jam events in the upper reach of the Catawba River based on a search of the USACE's Ice Jam Database 2012 version (USACE, 2015). Water temperatures in this area of the southeast United States consistently remain above freezing. Therefore, the licensee concluded that ice-induced flooding will not produce a credible maximum water level at the site and is not considered a realistic external flooding hazard to Catawba, Units 1 and 2 (Duke, 2014b). The staff confirmed through a review of the latest USACE's Ice Jam Database (USACE, 2015) that there are no recorded ice jams on the Catawba River, and agrees with the licensee's position that there are no flooding impacts from ice-induced events at the Catawba site.

The staff confirms the licensee's conclusion that the flood hazard from ice-induced flooding alone would not inundate the site. Therefore, ice-induced flooding does not need to be analyzed in a focused evaluation or an integrated assessment.

3.8 Channel Migrations or Diversions

The licensee reported in its FHRR that the reevaluated hazard for channel migrations or diversions does not impact the site as it is not a credible flooding event for the Catawba site. This flood-causing mechanism is not discussed in the licensee's CDB because channel migration or diversion flooding was never postulated to impact the site (Duke, 2014b).

Section 2.7 of the FHRR states that the Catawba River is regulated by a series of back-to-back dams and reservoirs. As such, the backwater effects of each dam mitigate reservoir velocities that would be necessary to produce a channel diversion. Over a period of more than a hundred years of regulation, the section of the Catawba River where the Catawba site is located has not exhibited any tendency to meander toward or migrate away from the Catawba site. Therefore, the licensee concluded that channel diversion on the Catawba River is not considered a credible flooding event (Duke, 2014b).

Based on the review of the information in the FHRR, the staff concurs with the licensee's conclusion that the hazard from channel migrations or diversions flooding would not impact the site. Therefore, channel migration or diversion flooding does not need to be analyzed in a focused evaluation or an integrated assessment.

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

4.1 Reevaluated Flood Elevation for Hazards Not Bounded by the CDB

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

Consistent with the process and guidance discussed in COMSECY-15-0019 (NRC, 2015c) and JLD-ISG-2016-01, Revision 0 (NRC, 2016c), the NRC staff anticipates 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 the licensee will perform additional assessments of plant response, either a focused evaluation or an integrated assessment, as discussed in COMSECY-15-0019 (NRC, 2015c) and JLD-ISG-2016-01, Revision 0 (NRC, 2016c).

4.2 Flood Event Duration for Hazards Not Bounded by the CDB

The staff reviewed information provided in Duke's 50.54(f) responses (Duke, 2014b; Duke, 2014c; Duke, 2014d; Duke, 2015; and NRC, 2016b) regarding the FED parameters needed to perform the additional assessments of plant response for flood hazards not bounded by the CDB. The FED parameters for the flood-causing mechanisms not bounded by the CDB are summarized in Table 4.2-1.

The licensee did not provide warning time parameters for LIP, but stated that the warning time for the LIP event will be determined using NEI 15-05 (Duke, 2015). The LIP event creating the maximum water elevations and inundation periods for different locations across the power block are listed in Table 2.1.4-1 in the FHRR (Duke, 2014b). The licensee used the modeling methods as described in Section 3.2 of this staff assessment to determine the FED parameters. The staff noted that the inundation period at the maximum water elevation for Unit 1 side of the powerblock was 4.2 hours (Duke, 2014b). The staff confirmed that the licensee's reevaluation of the inundation periods for LIP and associated drainage used present-day methodologies and regulatory guidance. The licensee did not provide the recession period for LIP, but the NRC staff would expect the recession time for LIP to have minimal impacts on the site.

For rivers and streams PMF, the licensee stated that the serial warning time trigger points at locations near the plant site were established at [[ ]] prior to a potential flood event at the Catawba site (Duke, 2015). To determine the adequacy of the warning times, the staff reviewed the PMF hydrograph presented in Figure 2.2.1-2 in the FHRR (Duke, 2014b) and determined that the propagation time from the onset of the main PMF event to the arrival time the PMF at the plant site is about [[ ]]. Therefore, staff determined that the range of the licensee-proposed warning time trigger points adequately covers the PMF propagation time for the river basin. The licensee did not provide the period of inundation and recession times because the PMF flood elevation is bounded by the combined dam failure event and is well below the plant grade. The staff agrees with the licensee's conclusion regarding the warning time, period of inundation, and period of recession.

For the combined dam failure flood event, the licensee did not provide the warning time for any of the three events analyzed, but stated that the warning time will be provided in an additional assessment submittal and will be based on industry guidance (Duke, 2015). The inundation durations at the Catawba intake and the SNSWP dam PMF would be [[ ]], respectively (Duke, 2015). These duration parameters were estimated based on a simulation of HEC-RAS under the assumption that the amount of overtopping of the [[ ]] of the Cowans Ford Dam resulted in an [[ ]] structures (Duke, 2014b; Duke, 2014d; and Duke, 2015). The staff checked the inundation periods in FHRR Table 2.8.1-1 with the HEC-RAS output files provided by the licensee and confirmed that these inundation duration parameters are accurate. The staff also reviewed the HEC-RAS modeling for the combined dam failure scenario and confirmed that the modeling is acceptable as discussed in Section 3.4 of this staff assessment. The licensee did not provide an inundation time for the Allison Creek Catawba discharge. The licensee also did not provide the recession period for any of the combined dam failure events, but stated that it will be provided in an additional assessment submittal and will be based on industry guidance (Duke, 2015).

The licensee stated (Duke, 2015) that the missing FED parameters will be included in additional assessments. The licensee is expected to develop the missing FED parameters for these flood-causing mechanisms to conduct the MSA and the focused evaluations or integrated assessment. The NRC staff will review these FED parameters as part of future additional assessments of plant response, if applicable to the assessment and hazard mechanism.

4.3 Associated Effects for Hazards Not Bounded by the CDB

The staff reviewed information provided in Duke's 50.54(f) response (Duke, 2014b; Duke, 2014c; Duke, 2014d; Duke, 2015; and NRC, 2016b) regarding AE parameters needed to perform future additional assessments of plant response for flood hazards not bounded by the CDB. AE parameters directly related to maximum total water height, such as waves and runup, are presented in Table 4.1-1. AE parameters not directly associated with total water height are listed in Table 4.3-1.

For the LIP event, the licensee stated (in FHRR Table 2.1.4-1) that the hydrodynamic load would be minimal because the maximum LIP flow velocity would be 2.6 f/s (0.79 m/s) and the maximum inundation depth would be 2.1 ft (0.64 m) (Duke, 2014b). The licensee also stated that the effects of debris is negligible by eliminating credible debris fields through appropriate Catawba operation procedures (Duke, 2015). For groundwater ingress, the licensee states that the duration of the flood events are short and thus not expected to have an impact (Duke, 2015). The licensee also concluded that associated effects for LIP are not applicable to the site for sediment loading, sediment deposition and erosion, concurrent conditions, and other pertinent factors (Duke, 2015). Based on the review of the licensee-provided LIP model input and output files (Duke, 2014d), the staff confirmed that the above inundation depths and flow velocities are correct and the modeling is acceptable as described in Section 3.2 of this report. Therefore, the staff concurs with the licensee's conclusion that the AE parameters for LIP are either minimal or not applicable.

For PMF and combined dam failure events, the debris effects on the Catawba intake are insignificant as the structure is located in the protective cove that is not directly aligned with the main channel, even though the main channel could generate large floating debris from trees or floating docks (Duke, 2015). The licensee stated in the FHRR that the combined dam failure event bounds PMF because the Catawba intake is located in a protective cove in which the flow velocities are lower than those of the main channel (Duke, 2014b). Therefore, hydrodynamic and debris loading will not have an impact on the site. The licensee also stated that the associated effects caused by sediment deposition and erosion, sediment loading, and groundwater ingress for both PMF and combined dam failure events are found to not challenge the site because the duration of the flood events are short (Duke, 2015). The staff also concluded that the site is not affected by concurrent conditions or other pertinent factors. The staff reviewed the licensee-provided topographic maps and Google maps and confirmed that PMF and combined dam failure floods will not directly impact the plant facilities as the plant site and Catawba intake are isolated from the river by a protective cove. The NRC staff agrees with the licensee's conclusion that potential associated effects related to PMF and dam failure either do not impact the site or are not applicable.

The staff concludes the licensee's methods were appropriate and the AE parameter results are reasonable for use in additional assessments associated with the MSA and the focused evaluations or integrated assessment.

4.4 Conclusion

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

The licensee is expected to develop missing FED parameters to conduct the MSA and the focused evaluations or integrated assessment. The staff will evaluate the missing FED parameters (i.e., warning time, period of inundation, and recession time) marked as "not provided" in Tables 4.2-1 and 4.3-1 during its review of the MSA.

5.0 CONCLUSION

The NRC staff has reviewed the information provided for the reevaluated flood-causing mechanisms for Catawba, Units 1 and 2. Based on its review of available information provided in Duke's 50.54(f) response, (Duke, 2014b; Duke, 2014c; Duke, 2014d; Duke, 2015; and NRC, 2016b) the staff concludes that the licensee conducted the hazard reevaluation using present-day methodologies and regulatory guidance used by the NRC staff in connection with ESP and COL reviews.

Based upon the preceding analysis, the NRC staff confirms 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 staff confirms the licensee's conclusions that (a) the reevaluated flood hazard results for LIP (for Unit 1), streams and rivers PMF, and dam failure are not bounded by the CDB flood hazard; (b) a focused evaluation or additional assessments of plant response will be performed for the LIP, rivers and streams, and combined dam failure flood-causing mechanisms; and (c) the reevaluated flood-causing mechanism information is appropriate input to additional assessments of plant response, as described in the 50.54(f) letter, COMSECY-15-0019, and associated guidance.

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.

U.S. Nuclear Regulatory Commission Documents and Publications

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

NRC, 2011a, "Near-Term Report and Recommendations for Agency Actions Following the Events in Japan," Commission Paper SECY-11-0093, July 12, 2011, ADAMS Accession No. ML11186A950.

NRC, 2011b, "Recommendations for Enhancing Reactor Safety in the 21st Century: The Near-Term Task Force Review of Insights from the Fukushima Dai-Ichi Accident," Enclosure to Commission Paper SECY-11-0093, July 12, 2011, ADAMS Accession No. ML111861807.

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

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

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

NRC, 2012a, letter from Eric J. Leeds, Director, Office of Nuclear Reactor Regulation and Michael R. Johnson, Director, Office of New Reactors, to All Power Reactor Licensees and Holders of Construction Permits in Active or Deferred Status, "Request for Information Pursuant to Title 10 of the *Code of Federal Regulations* 50.54(f) Regarding the Recommendations 2.1, 2.3, and 9.3, of the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident," March 12, 2012, ADAMS Accession No. ML12056A046.

NRC, 2012b, letter from Eric J. Leeds, Director, Office of Nuclear Reactor Regulation, to All Power Reactor Licensees and Holders of Construction Permits in Active or Deferred Status, "Issuance of Order to Modify Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events," Order EA-12-049, March 12, 2012, ADAMS Accession No. ML12054A736.

NRC, 2012c, letter from Eric J. Leeds, Director, Office of Nuclear Reactor Regulation, to All Power Reactor Licensees and Holders of Construction Permits in Active or Deferred Status, "Prioritization of Response Due Dates for Request for Information Pursuant to Title 10 of the *Code of Federal Regulations* 50.54(f) Regarding Flooding Hazard Reevaluations for

Recommendation 2.1 of the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident," May 11, 2012, ADAMS Accession No. ML12097A510.

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

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

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

NRC, 2014a, "Catawba Nuclear Station, Units 1 and 2: Request for Additional Information Regarding Flood Hazard Reevaluation Report (TAC Nos. MF3625 and MF3626)," June 6, 2014, ADAMS Accession No. ML14156A130.

NRC, 2014b, "Catawba Nuclear Station, Units 1 and 2 – Staff Assessment of the Flooding Walkdown Report Supporting Implementation of the Near-Term Task Force Recommendation 2.3 Related to the Fukushima Dai-Ichi Nuclear Power Plant Accident (TAC Nos. MF0210 and MF0211)," June 11, 2014, ADAMS Accession No. ML14153A662.

NRC, 2015a, "Catawba Nuclear Station – Fukushima 2.1 Flooding – FHRR Review RAIs," NRC Electronic Email dated April 29, 2015, ADAMS Accession No. ML15119A193.

NRC, 2015b, "Nuclear Regulatory Commission Plan for the Audit of Duke Carolinas, LLC.'s Flood Hazard Reevaluation Report Submittal Relating to the Near-Term Task Force Recommendation 2.1 Flooding for Catawba Nuclear Station, Units 1 and 2 (TAC Nos. MF3625 and MF3626)," June 8, 2015, ADAMS Accession No. ML15155A631.

NRC, 2015c, "Closure Plan for the Reevaluation of Flooding Hazard for Operating Nuclear Power Plants," Commission Paper COMSECY-15-0019, June 30, 2015, ADAMS Accession No. ML15153A104.

NRC, 2015d, "Catawba Nuclear Station, Units 1 and 2 – Revised Interim Staff Response to the Reevaluated Flood Hazards Submitted in Response to 10 CFR 50.54(f) Information Request – Flood-Causing Mechanism Reevaluation (TAC Nos. MF3625 and MF3626)," December 21, 2105, ADAMS Accession No. ML15352A247.

NRC, 2016a, "Compliance with Order EA-12-049 Order to Modify Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events," Interim Staff Guidance JLD-ISG-2012-01, Revision 1 and Comment Resolution, January 22, 2016, ADAMS Accession No. ML15357A142.

NRC, 2016b, "Nuclear Regulatory Commission Report for the Audit of Duke Carolinas, LLC.'s Flood Hazard Reevaluation Report Submittal Related to the Near-Term Task Force Recommendation 2.1 Flooding for: Catawba Nuclear Station, Units 1 and 2 (CAC Nos. MF3625 and MF3626)," May 4, 2016, ADAMS Accession No. ML16112A040 (Not publicly available).

NRC), 2016c, Interim Staff Guidance JLD-ISG-2016-01, Revision 0, "Guidance for Activities Related to Near-Term Task Force Recommendation 2.1, Flooding Hazard Reevaluation; Focused Evaluation and Integrated Assessment," July 11, 2016, ADAMS Accession No. ML16162A301.

Codes and Standards

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

Other References

Duke (Duke Energy Carolinas, LLC.), 2012, "Catawba Nuclear Station (CNS), Units 1 and 2, Docket Nos 50-413 and 50-414, Renewed License Nos. NPF-3 and NPF-52, Flooding Walkdown Information Requested by NRC Letter, Request for Information Pursuant to Title 10 of the *Code of Federal Regulations 50.54(f)* Regarding Recommendations 2.1, 2.3, and 9.3, of the Near-Term Task Force Review of Insights from the Fukushima Dai-Ichi Accident; dated March 12, 2012," November 27, 2012, ADAMS Accession No. ML12334A444.

Duke, 2014a, "Catawba, Units 1 & 2 - Response to NRC 10 CFR 50.54(f) Request for Information Regarding Near-Term Task Force Recommendation 2.3, Flooding Update - Review of Available Physical Margin (APM) Assessments," February 12, 2014, ADAMS Accession No. ML14051A352.

Duke, 2014b, "Flood Hazard Reevaluation Report, Response to NRC 10 CFR 50.54(f) Request for Additional Information Pursuant to Title 1 0 of the Code of Federal Regulations 50.54(f) regarding Recommendations 2.1, 2.3 and 9.3 of the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident, Dated March 12, 2012," March 12, 2014, ADAMS Accession No. ML14077A054 (Not publicly available).

Duke, 2014c, "Catawba Nuclear Station, Units 1 and 2, Request for Additional Information Regarding Fukushima Flood Hazard Reevaluation Report," July 7, 2014, ADAMS Accession No. ML14225A774 (Not publicly available).

Duke, 2014d, "Catawba Nuclear Station, Units 1 and 2, Request for Additional Information Regarding Fukushima Flood Hazard Reevaluation Report," November 25, 2014, ADAMS Accession No. ML14303A192

Duke, 2015. "Catawba Nuclear Station, Units1 and 2, Response to NRC Request for Additional Information Regarding the Flood Hazard Reevaluation Report (FHRR)." July 28, 2015, ADAMS Accession No. ML15222A535 (Not Publicly Available).

FERC (Federal Energy Regulatory Commission), 2006. "Engineering Guidelines for the Evaluation of Hydropower Projects, Chapter IV Embankment dams (Draft)," September 2006.

Fread, D. L., 1991. "The NWS DAMBRK Model: Theoretical Background/User Documentation," National Weather Service, Silver Spring, Maryland, June 20, 1998 (Revision 4, August 1991). Available online at
http://www.nws.noaa.gov/oh/hrl/hsmb/docs/hydraulics/papers_before_2009/DAMBRK.pdf.

Froehlich, David C., 1995, "Peak Outflow from Breached Embankment dam," Journal of Water Resources Planning and Management, vol. 121, no. 1, p. 90-97.

GEO-SLOPE (GEO-SLOPE International Ltd.), 2012. "Stability Modeling with SLOPE/W, An Engineering Methodology," November 2012 Edition.

Google, n.d., "Google Maps" (Web site), https://www.google.com/maps, accessed July 19, 2016.

HDR Engineering, 2014, Catawba, Units 1 and 2 - Fukushima External Flood Evaluation Calculation CNS-194292-010, "External Flooding and dam Failure," attached to Duke (2014b) dated on July 7, 2014, ADAMS Accession No. ML14225A774 (Not Publicly Available).

Innovyze, 2012, Innovyze Infoworks ICM (Integrated Catchment Model), Version 3.0 software 2012.

Leenknecht, D.A., Szuwalski, A. and Sherlock, A.R. (1992), "Automated Coastal Engineering System: User's Guide," U.S. Army Corps of Engineers, Coastal Engineering Research Center, Waterways Experiment Station, Vicksburg, MS.

Lynett, P.J., Wu, Y.-R., and Liu, P.L.-F. (2002), "Modeling Wave Runup with Depth-Integrated Equations." Coastal Engineering, 46(2), 89-107.

NOAA (National Oceanic and Atmospheric Administration), 1978, "Probable Maximum Precipitation Estimates, United States, East of the 105th Meridian," NOAA Hydrometeorological Report No. 51, June 1978.

NOAA, 1982, "Application of Probable Maximum Precipitation Estimates, United States, East of the 105th Meridian," NOAA Hydrometeorological Report No. 52, August 1982.

NEI (Nuclear Energy Institute), 2015, "Diverse and Flexible Coping Strategies (FLEX) Implementation Guide," NEI 12-06 Revision 2, December 2015, ADAMS Accession No. ML16005A625.

SCS (Soil Conservation Service), 1986, "Urban Hydrology for Small Watersheds," Technical Release 55, Soil Conservation Service, U.S. Department of Agriculture, June 1986.

USACE (U.S. Army Corps of Engineers), 1998, HEC-1 Flood Hydrograph Package User's Manual, CPD-1A Version 4.1. Hydrologic Engineering Center, June 1998, Available online at http://www.hec.usace.army.mil/publications/ComputerProgramDocumentation/HEC-1_UsersManual_%28CPD-1a%29.pdf.

USACE, 2003, "Coastal Engineering Manual," Engineer Manual EM 1110-2-1100, Revision 1, U.S. Army Corps of Engineers, 2003.

USACE, 2010, "River Analysis System (HEC-RAS), Version 4.1.0," Hydrologic Engineering Center, U.S. Army Corps of Engineers, January 2010.

USACE, 2015, "Ice Jam Database," U.S. Army Corps of Engineers, Cold Region Research and Engineering Laboratory (CRREL), available at: http://www.crrel.usace.army.mil/technical_areas/hh/, accessed on April 2, 2015.

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

Notes:

SRP is the Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition (NRC, 2007)
JLD-ISG-2012-06 is the "Guidance for Performing a Tsunami, Surge, or Seiche Hazard Assessment" (NRC, 2013a)
JLD-ISFG-2013-01 is the "Guidance for Assessment of Flooding Hazards Due to dam Failure" (NRC, 2013b)

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

Reevaluated Flood-Causing Mechanisms and Associated Effects that May Exceed the Powerblock Elevation (593.50 ft (180.90 m) MSL)[1,2]	**ELEVATION ft (m) MSL**
Local Intense Precipitation and Associated Drainage	
Unit 1 side of the yard	595.5 (181.51)
Unit 2 side of the yard	595.6 (181.54)
Failure of dams and Onsite Water Control/Storage Structures (with Standard Project Flood and Wind Effects)	
Lake Wylie CNS intake (Combined Effects)	[[ ]]
Standby Nuclear Service Water Pond (Combined Effects)	[[ ]]
Allison Creek CNS Discharge (Combined Effects)	[[ ]]

Source: Duke, 2014b

Notes:

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

[2] The reevaluated hazard for Streams and Rivers, results in a stillwater surface elevation of 590.7 ft (180.05m) MSL for Lake Wylie CNS intake (unbounded) and for the SNSWP dam including wind, wave and runup is an elevation of MSL (bounded), which are below the powerblock elevation of 593.50 ft (180.90m) MSL and so are omitted here.

Table 3.1-2. Current Design Basis Flood Hazards

Flooding Mechanism	Stillwater Elevation	Waves/ Runup	Design Basis Hazard Elevation	Reference
Local Intense Precipitation				Response to NRC Request for Additional Information Regarding the FHRR, dated July 28, 2015 (ADAMS Accession No. ML15222A535)
Unit 1 Side of the yard	594.9 ft MSL	Minimal	594.9 ft MSL	
Unit 2 Side of the yard	595.9 ft MSL	Minimal	595.9 ft MSL	
Streams and Rivers				
Lake Wylie CNS intake	581.1 ft MSL	Not applicable	581.1 ft MSL	FHHR Section 1.2.2 and Table 3-1
SNSWP dam	583.5 ft MSL	1.0 ft	584.5 ft MSL	FHRR Section 1.2.2
Failure of dams and Onsite Water Control/Storage Structures				
Lake Wylie CNS intake (Combined Effects)	592.4 ft MSL	1.5 ft	593.9 ft MSL	FHRR Table 1.2.8-1
SNSWP dam (Combined Effects)	592.4 ft MSL	2.2 ft	594.6 ft MSL	FHRR Table 1.2.8-1
Allison Creek CNS Discharge (Combined Effects)	592.4 ft MSL	1.2 ft	593.6 ft MSL	FHRR Table 1.2.8-1
Storm Surge				
Lake Wylie Storm Surge and Seiche	569.4 ft MSL	8.4 ft MSL	577.8 ft MSL	FHRR Section 1.2.4
Seiche	No impact on the site identified	No impact on the site identified	No impact on the site identified	FHRR Section 1.2
Tsunami	Not included in CDB	Not included in CDB	Not included in CDB	FHRR Section 1.2
Ice-Induced	No impact on the site identified	No impact on the site identified	No impact on the site identified	FHRR Section 1.2

Channel Migrations or Diversions	No impact on the site identified	No impact on the site identified	No impact on the site identified	FHRR Section 1.2

Source: NRC, 2015d
Note: 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 the CDB

Flood-Causing Mechanism	Stillwater Elevation	Waves/ Runup	Reevaluated Hazard Elevation	Reference
Local Intense Precipitation				
Unit 1 Side of the yard	595.5 ft MSL	Minimal	595.5 ft MSL	FHRR Section 2.1 and Table 3-1
Streams and Rivers				
Lake Wylie CNS intake	590.7 ft MSL	Not applicable	590.7 ft MSL	FHRR Section 2.2
Failure of dams and Onsite Water Control/Storage Structures				
Lake Wylie CNS intake (Combined Effects)	[[ ]]	1.0 ft	[[ ]]	FHRR Section 2.8.1, table 3-1, and Table 2.8.1-1
Standby Nuclear Service Water Pond (Combined Effects)	[[ ]]	1.0 ft	[[ ]]	FHRR Table 2.4.2-1, Table 3-1, and Table 2.8.1-1
Allison Creek CNS Discharge (Combined Effects)	[[ ]]	Not applicable	[[ft]]	FHRR Table 2.3.2-4 and Table 3-1

Source: NRC, 2015d
Note:
Reported values are rounded to the nearest one-tenth of a foot.

Table 4.2-1. Flood Event Durations 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 (Unit 1)	Not provided	4.2 hours for Unit 1 Side of the yard	Not provided
Rivers and Streams PMF	Up to 144 hours for all three dam locations	Not applicable as PMF is Bounded by the dam Failure Flood	Not applicable as PMF is Bounded by the dam Failure Flood
Failure of dams and Onsite Water Control/Storage Structures			
Lake Wylie CNS intake (Combined Effects)	Not provided	[[ ]]	Not provided
SNSWP dam (Combined Effects)	Not provided	[[ ]]	Not provided
Allison Creek CNS Discharge (Combined Effects)	Not provided	Not provided	Not provided

Source: Duke, 2014b and Duke, 2015

TABLE 4.3-1. ASSOCIATED EFFECTS PARAMETERS NOT DIRECTLY ASSOCIATED WITH TOTAL WATER HEIGHT FOR FLOOD-CAUSING MECHANISMS NOT BOUNDED BY THE CDB

	Flooding Mechanism		
Associated Effects Parameter	**Local Intense Precipitation**	**PMF**	**dam Failure[1]**
Hydrodynamic loading at plant grade	Minimal	No impact on the site identified	No impact on the site identified
Debris loading at plant grade	Not Applicable	No impact on the site identified	No impact on the site identified
Sediment loading at plant grade	Not Applicable	No impact on the site identified	No impact on the site identified
Sediment deposition and erosion	Not Applicable	No impact on the site identified	No impact on the site identified
Concurrent conditions, including adverse weather	Not Applicable	Not Applicable	Not Applicable
Groundwater ingress	Not Applicable	Not Applicable	Not Applicable
Other pertinent factors (e.g., waterborne projectiles)	Not Applicable	Not Applicable	Not Applicable

Source: Duke, 2014b and Duke, 2015
Notes:
[1]This event bounds the PMF

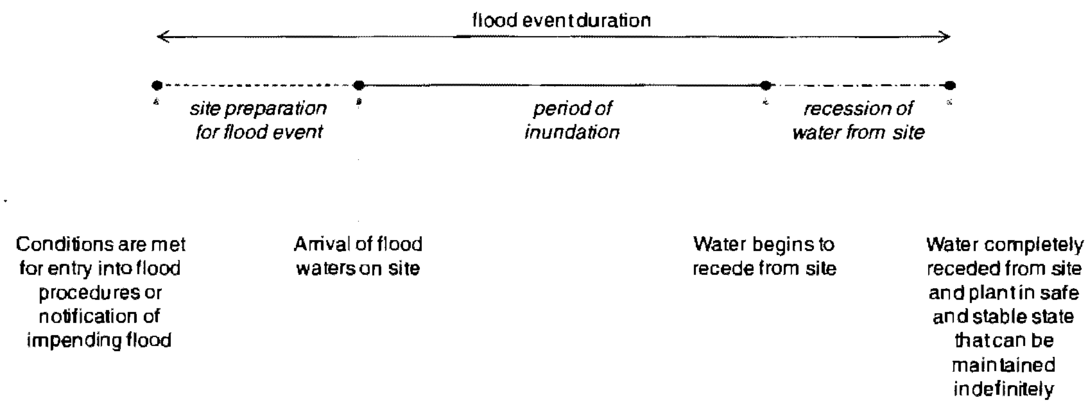

Figure 2.2-1. Flood Event Duration (NRC, 2012d)

Figure 3.1-1. Location of CNS Site and SNSWP dam adjacent to Lake Wylie (Base map from Google Maps (Google, n.d.) and locations of map features from Duke, 2014b)

Figure 3.2-1. CNS Site and 2-D Model Domain Used in the LIP Evaluation (Duke, 2014b)

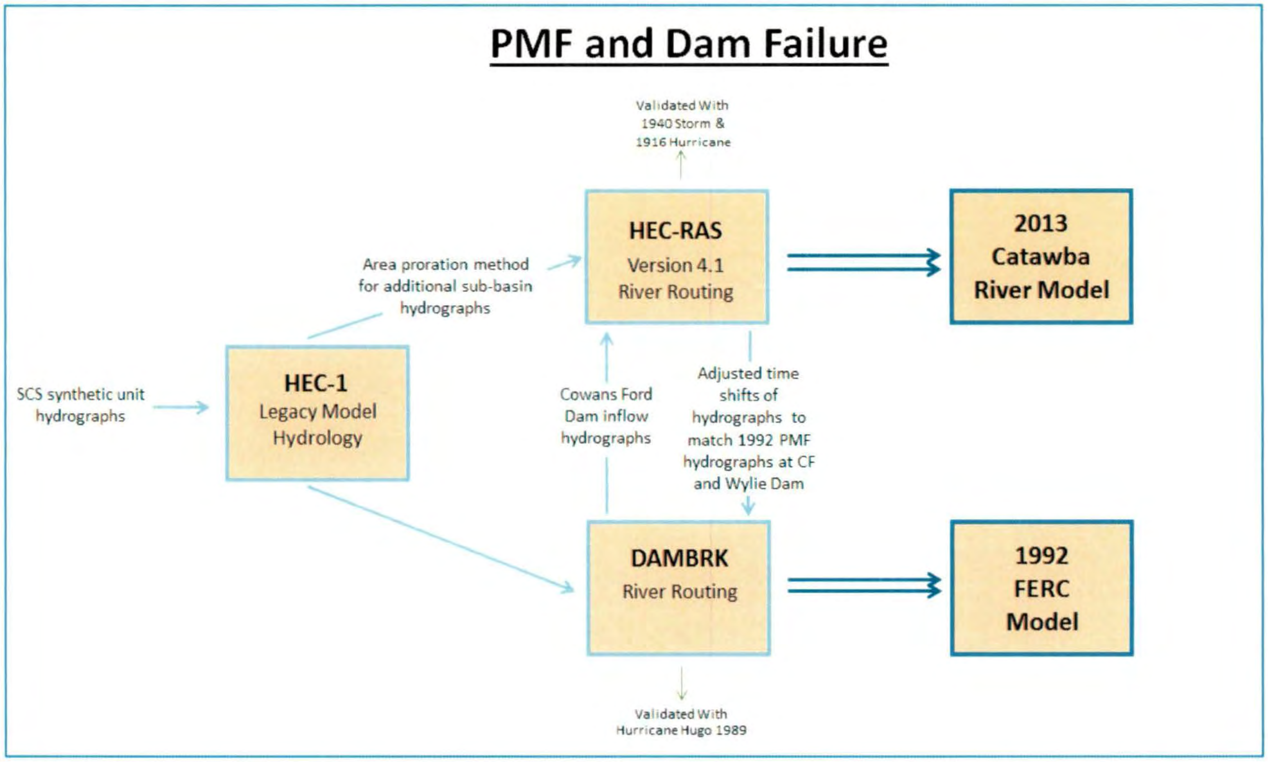

Figure 3.3-1. Historical Development of Catawba River Model (Derived from HDR Engineering, 2014)

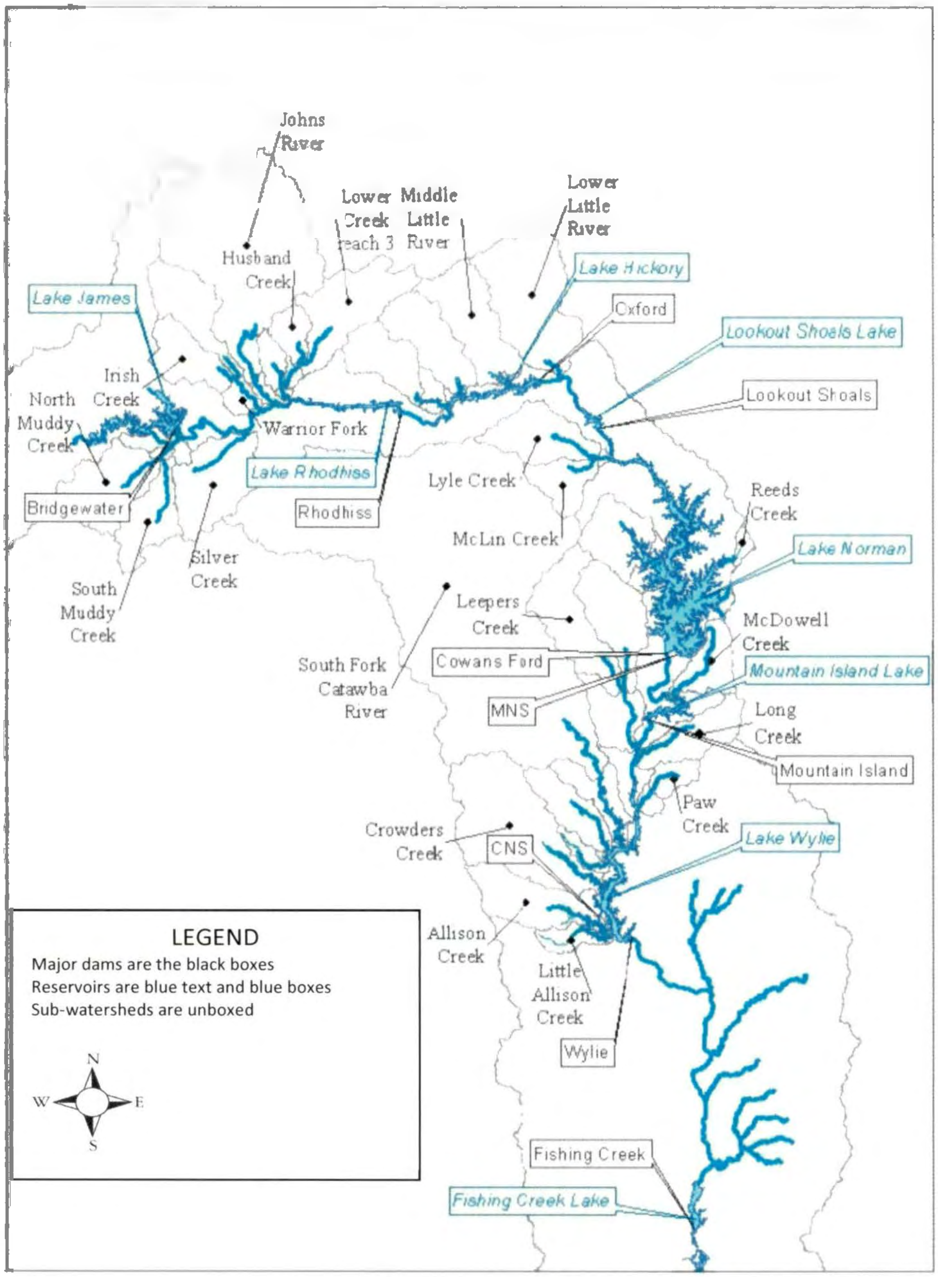

Figure 3.4-1. Overview map of Catawba River watershed, showing major dams, reservoirs, and sub-watersheds (derived from Duke, 2014b)

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

Sincerely,

/RA/

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

Docket Nos. 50-413 and 50-414

Enclosure:
Summary of Results of Flooding
Hazard Re-Evaluation Report

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