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

May 3, 2019

Mr. Robert T. Simril
Site Vice President
Duke Energy Carolinas, LLC
Catawba Nuclear Station
14800 Concord Road
York, SC 29745

SUBJECT: CATAWBA NUCLEAR STATION, UNITS 1 AND 2 – STAFF ASSESSMENT OF FLOODING FOCUSED EVALUATION (EPID NO. L-2018-JLD-0178)

Dear Mr. Simril:

By letter dated December 6, 2018 (ADAMS Accession No. ML18344A052), Duke Energy Carolinas, LLC (the licensee) submitted the focused evaluation (FE) for the Catawba Nuclear Station, Units 1 and 2 (Catawba). The purpose of this letter is to provide the NRC's assessment of the Catawba FE.

By letter dated March 12, 2012 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML12053A340), 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, under Title 10 of the *Code of Federal Regulations* (10 CFR), Section 50.54(f), (hereafter referred to as the "50.54(f) letter"). The request was issued in connection with implementing lessons learned from the 2011 accident at the Fukushima Dai-ichi nuclear power plant, as documented in the NRC's Near-Term Task Force (NTTF) report (ADAMS Accession No. ML111861807). Enclosure 2 to the 50.54(f) letter requested that licensees reevaluate flood hazards for their sites using present-day methods and regulatory guidance used by the NRC staff when reviewing applications for early site permits and combined licenses (ADAMS Accession No. ML12056A046). By letter dated March 12, 2014 (ADAMS Accession No. ML14077A054), the licensee responded to this request for Catawba.

By letter dated December 21, 2015 (ADAMS Accession No. ML15352A247), the NRC issued an interim staff response (ISR) letter for Catawba. The ISR letter provided the reevaluated flood hazard mechanisms that exceeded the design basis and parameters that are a suitable input for subsequent flooding reviews. As stated in the ISR letter, because the local intense precipitation, combined effects probable maximum flooding from streams and rivers, and failure of dams and onsite water control/storage structures are not fully bounded by the plant's design basis, additional assessments of those flood hazard mechanisms are necessary. The complete staff assessment for the reevaluation of the flooding hazard was issued by letter dated September 30, 2016 (ADAMS Accession No. ML16251A281).

Enclosure 1 transmitted herewith contains Security-Related Information and Critical Electric Infrastructure Information (CEII). When separated from Enclosure 1, this document is decontrolled.

The FEs are intended to confirm that licensees have adequately demonstrated, for the unbounded mechanisms identified in the ISR letter, that: 1) a flood mechanism is bounded based on further reevaluation of flood mechanism parameters; 2) effective flood protection is provided for the unbounded mechanism; or 3) a feasible response is provided if the unbounded mechanism is local intense precipitation.

As described in the attached staff assessment, the NRC staff has concluded that the Catawba FE was performed consistent with the guidance described in Nuclear Energy Institute (NEI) 16-05, Revision 1, "External Flooding Assessment Guidelines" (ADAMS Accession No. ML16165A178). Guidance document NEI 16-05, Revision 1, has been endorsed by Japan Lessons-Learned Division (JLD) interim staff guidance (ISG) JLD-ISG-2016-01, "Guidance for Activities Related to Near-Term Task Force Recommendation 2.1, Flood Hazard Reevaluation" (ADAMS Accession No. ML16162A301). The NRC staff has further concluded that the licensee has demonstrated that effective flood protection, if appropriately implemented, exists for the unbounded flooding mechanisms at Catawba. This closes out the licensee's response for Catawba for the reevaluated flooding hazard portion of the 50.54(f) letter and the NRC's efforts associated with EPID No. L-2018-JLD-0178.

If you have any questions, please contact me at 301-415-2864 or via e-mail at Milton.Valentin@nrc.gov.

Sincerely,

Milton O. Valentín, Project Manager
Beyond-Design-Basis Management Branch
Division of Licensing Projects
Office of Nuclear Reactor Regulation

Enclosures:
1. Staff Assessment Related to the Flooding Focused Evaluation for Catawba (Non-public, Security Related)
2. Staff Assessment Related to the Flooding Focused Evaluation for Catawba (Public)

Docket Nos. 50-413 and 50-414

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STAFF ASSESSMENT BY THE OFFICE OF NUCLEAR REACTOR REGULATION RELATED TO THE FOCUSED EVALUATION FOR CATAWBA NUCLEAR STATION, UNITS 1 AND 2 AS A RESULT OF THE REEVALUATED FLOODING HAZARD NEAR-TERM TASK FORCE RECOMMENDATION 2.1 - FLOODING

1.0 INTRODUCTION

By letter dated March 12, 2012 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML12053A340), 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, under Title 10 of the *Code of Federal Regulations* (10 CFR), Section 50.54(f) (hereafter referred to as the "50.54(f) letter"). The request was issued in connection with implementing lessons learned from the 2011 accident at the Fukushima Dai-ichi nuclear power plant, as documented in the NRC's Near-Term Task Force (NTTF) report (ADAMS Accession No. ML111861807).

Enclosure 2 of the 50.54(f) letter requested that licensees reevaluate flood hazards for their respective sites using present-day methods and regulatory guidance used by the NRC staff when reviewing applications for early site permits and combined licenses (ADAMS Accession No. ML12056A046). If the reevaluated hazard for any flood-causing mechanism is not bounded by the plant's design basis flood hazard, an additional assessment of plant response would be necessary. Specifically, the 50.54(f) letter stated that an integrated assessment should be submitted and described the information that the integrated assessment should contain. By letter dated November 30, 2012 (ADAMS Accession No. ML12311A214), the NRC staff issued Japan Lessons-Learned Project Directorate[1] (JLD) interim staff guidance (ISG) JLD-ISG-2012-05, "Guidance for Performing the Integrated Assessment for External Flooding."

On June 30, 2015 (ADAMS Accession No. ML15153A104), the NRC staff issued COMSECY-15-0019, describing the closure plan for the reevaluation of flooding hazards for operating nuclear power plants. The Commission approved the closure plan on July 28, 2015 (ADAMS Accession No. ML15209A682). COMSECY-15-0019 outlines a revised process for addressing cases in which the reevaluated flood hazard is not bounded by the plant's design basis. The revised process describes a graded approach in which certain licensees with hazards exceeding their design basis flood will not be required to complete an integrated assessment, but instead will perform a focused evaluation (FE). As part of the FE, these licensees will assess the impact of the hazard(s) on their site and then evaluate and implement any necessary programmatic, procedural, or plant modifications to address the hazard exceedance.

Nuclear Energy Institute (NEI) 16-05, Revision 1, "External Flooding Assessment Guidelines" (ADAMS Accession No. ML16165A178), has been endorsed by the NRC as an appropriate methodology for licensees to perform the FE in response to the 50.54(f) letter. The NRC's

[1] The Japan Lessons-Learned Project Directorate was subsequently replaced by the Japan Lessons-Learned Division, which uses the same initials (JLD). No distinction is made between the two organizations in this evaluation.

Enclosure 2

endorsement of NEI 16-05, including exceptions, clarifications, and additions, is described in NRC JLD-ISG-2016-01, "Guidance for Activities Related to Near-Term Task Force Recommendation 2.1, Flood Hazard Reevaluation" (ADAMS Accession No. ML16162A301).

2.0 BACKGROUND

Flood Hazard Reevaluation Report

By letter dated March 12, 2014 (ADAMS Accession No. ML14077A054), Duke Energy Carolinas, LLC (Duke, the licensee) submitted the flood hazard reevaluation report (FHRR) for the Catawba Nuclear Station, Units 1 and 2 (Catawba, the site). In this letter, Duke informed the NRC staff of three reevaluated flood hazard events (failure of dams and onsite water control/storage structures, combined effect probable maximum flood event flood (CE/PMF), and local intense precipitation (LIP)) exceeding the design basis flood. After reviewing the licensee's response, by letter dated December 21, 2015 (ADAMS Accession No. ML15352A247), the NRC issued an interim staff response (ISR) letter for Catawba. The ISR letter discussed the reevaluated flood hazard mechanisms that exceeded the design basis for Catawba and the parameters that are a suitable input for other assessments associated with NTTF Recommendation 2.1 "Flooding." As stated in the ISR letter, because the LIP, the CE/PMF, and failure of dams and onsite water control/storage structures are not fully bounded by the plant's design basis, additional assessments are necessary. The NRC staff final assessment of the FHRR was issued in a letter dated September 30, 2016 (ADAMS Accession No. ML16251A281).

Mitigation Strategies Assessment

By letter dated June 20, 2017 (ADAMS Accession No. ML17177A099), Duke submitted the flooding mitigation strategies assessment (MSA) for NRC review. The MSA discussed how the reevaluated flooding hazards affected their mitigation strategies for beyond design basis external events. In its MSA, the licensee refined the LIP, the CE/PMF, and failure of dams and onsite water control/storage structures flooding mechanisms and the NRC staff reviewed the implementation and results of these refinements. Based on the Commission direction in the Affirmation Notice and Staff Requirements Memorandum (SRM) dated January 24, 2019 (ADAMS Accession No. ML19023A038), the staff did not complete the documentation of the MSA review. However, the NRC staff gathered sufficient information of the hazard refinements during the MSA audit, as documented in Attachment 1 of this Enclosure. The results of the staff's review of the MSA hazard refinements are considered in the evaluation of the FE.

Focused Evaluation

By letter dated December 6, 2018 (ADAMS Accession No. ML18344A052), the licensee submitted the FE for Catawba. The FEs are intended to confirm that licensees have adequately demonstrated, for unbounded mechanisms identified in the ISR letter, that: 1) a flood mechanism is bounded based on further reevaluation of flood mechanism parameters; 2) effective flood protection is provided for the unbounded mechanism; or 3) a feasible response is provided if the unbounded mechanism is LIP. These 3 options associated with performing an FE are referred to as Paths 1, 2, or 3, as described in NEI 16-05, Revision 1. The purpose of this staff assessment is to provide the results of the NRC's evaluation of the Catawba FE.

3.0 TECHNICAL EVALUATION

As described in the ISR letter, the LIP, the CE/PMF, and failure of dams and onsite water control/storage structures were found to exceed the plant's design basis. However, the licensee made refinements to all the flooding mechanisms exceeding the design basis, as explained in section 3.1 of this assessment. The licensee stated that the FE followed Path 2 (demonstrate effective flood protection) of NEI 16-05, Revision 1, and followed guidance in NEI 16-05, Appendix B, to evaluate the site's strategy. However, some of the refinements done in the MSA, and being used in the FE, fall under Path 1 (demonstrate flood mechanism is bounded) of NEI 16-05, and should be evaluated following the criteria in Appendix A of the same document. This technical evaluation characterizes flood parameters and evaluates the following flood impact assessment topics for each unbounded flood-causing mechanism: a description of the impact of the unbounded hazard; an evaluation of available physical margin (APM) and reliability of flood protection features; and the overall site response.

3.1 Characterization of Flood Parameters

In its FE, the licensee described additional hazard refinements to the unbounded flooding mechanisms previously evaluated and documented in the ISR letter. The licensee refined the three unbounded flooding hazards in the MSA and these used as input for the FE. The licensee further revised the LIP evaluation to support the FE and provided additional details in the FE submittal. Using these refined flooding mechanisms from both the MSA and FE submittals, the licensee performed the FE and concluded that key safety functions (KSFs) (core cooling, containment, and spent fuel pool cooling) are not impacted by the unbounded reevaluated mechanisms. The licensee stated that the main reason to refine all unbounded flooding mechanisms was to introduce a more realistic quantification of flooding levels. Because the refined, unbounded flooding mechanisms differ from those accepted by the NRC staff in previous evaluations (i.e. the ISR and the FHRR staff assessment), the NRC staff reviewed the basis for these refinements and assessed how suitable these are for the FE.

Refined dam failures and combined events flood (CE/PMF)

The licensee's FE submittal states that the dam failure and CE/PMF mechanisms, used in the FE, were refined to support the flooding MSA. For this reason, the NRC staff reviewed the MSA and supporting information associated with the dam failure and CE/PMF refinements to complete the FE review. The licensee refined these flooding mechanisms by using the hierarchical hazard analysis process described in NUREG/CR-7046, "Design-Basis Flood Estimation for Site Characterization at Nuclear Power Plants in the United States of America" (ADAMS Accession No. ML11321A195). Originally, the licensee used data from the Hydrometeorological Report (HRM) 51, "Probable Maximum Precipitation Estimates, United States, East of the 105th Meridian," in its FHRR. As stated in Table A-1 of NEI 16-05, the use of HMR 51 is a conservative assumption for flooding in streams and rivers. In the MSA, the licensee refined the HMR 51-generated CE/PMF and applied a site-specific probable maximum precipitation (ssPMP) characterization for the Catawba River basin and used a more realistic precipitation loss method for modeling runoff in conjunction with the re-evaluation of the flood elevations for the postulated dam failures and combined effects. With the refinements, the licensee determined that flood hazards due to the streams and rivers flood-causing mechanism are bounded by the design basis, thus eliminating these hazards from further consideration. After evaluation, the NRC staff concludes that the licensee's refinement is in accordance with

NEI 16-05, Section 7.1, because its reduction in conservatism was done in accordance with NEI 16-05, Appendix A, and because the use of ssPMP provides more realism and accuracy.

(CEII) The licensee reported in the MSA that the refined maximum flood elevation with wind-driven wave runup for the combined dam failures event is [[ ]] at the Catawba intake structure, which is the point of interest for the site inundation analysis (see Figure 1).

The Catawba FHRR utilized the probable maximum precipitation (PMP) values determined from the application of HMR's 51 (from June 1978) and 52 (from August 1982), for flooding in rivers and streams, and for upstream dam failures. However, the licensee refined its analysis and the MSA and FE submittals use ssPMP values in lieu of the HMR PMP values described in the FHRR submittal.

The Catawba ssPMP analysis provides an alternative estimation of PMP values as compared to the conventional HMR PMP values. The Catawba ssPMP was developed using an additional 40 years of storm data in addition to HMR PMP storms and accounts for meteorological and topographic characteristics that are unique to the sub-watersheds within the Catawba-Wateree basin. To assess the reasonableness of the ssPMP analysis, the NRC staff:

- reviewed Duke's initial storm long list to identify any potentially controlling storms that may have not been evaluated by the licensee,
- reviewed Duke's storm short list to identify any missing storms, potential underestimates of rainfall rates, and errors in storm center locations and elevations,
- reviewed the dew point values used for each storm to estimate the total moisture available in the air mass that supplied that storm, and
- reviewed the orographic transposition factor (OTF) used for each storm to simulate the adjustment caused by terrain during storm transpositioning.

Attachment 1 of this assessment provides additional details of the information needs discussed during the audit and the topics reviewed by the NRC staff. In addition, the NRC staff performed an independent analysis with revised ssPMP input parameters, which included storm representative dew points, in-place maximum dew points, transpositioned maximum dew points, and terrain adjustment. The NRC staff performed independent ssPMP sensitivity analyses to assess the implications of using revised ssPMP calculation approaches and applying different calculation parameters. The NRC staff then conducted a hydrologic and hydraulic sensitivity analysis using its own ssPMP calculation results.

During the audit, the NRC staff requested the licensee to explain how the meteorological and hydrological characteristics of severe storms in this region were considered when distributing the ssPMP in space. In its response, the licensee stated that they used the spatial pattern of five historical storms (1908, 1916, 1929, 1940, and 1945 events) individually. The licensee also clarified that they did not shift the storm centers (e.g., to the basin center) to create an optimal storm pattern that would generate the most critical flood level at the plant site as is usually done for riverine PMF simulations (see NUREG/CR-7046). To check the effects of the spatial ssPMP variations on the flood hazards, the NRC staff performed the following two confirmatory analyses:

- The NRC staff examined the variability of the NRC staff-estimated ssPMP values by subbasin for the five licensee-selected storms (see Figure 2). As a result, the NRC staff found the five selected storms provide sufficient spatial variability in all subbasins. The NRC staff also plotted, for each storm, the pattern of spatial adjustment factors that are representative of the observed rainfall as it fell spatially within the basin but does not align with the theoretical PMP pattern (see Figure 2). From these maps, the NRC staff confirmed that the spatial patterns used by the licensee represent sufficiently diverse storm centers: two upstream, two downstream, and one midstream.

- Using the refined hydrologic and hydraulic (H&H) models and the combined dam failure scenario as a base condition, the NRC staff performed sensitivity runs with six different staff-estimated ssPMP distributions: five tropical storm patterns and one general storm pattern. The NRC staff's results indicate that the maximum flood elevations at the plant site are insensitive to the spatial pattern of the ssPMP (i.e., approximately **[[ ]]** changes in flood levels) (see Table 5). ~~(CEII)~~

From the above analysis, the NRC staff determined that the licensee's ssPMP spatial distributions are adequate for use in their hydrologic simulations. For the ssPMP distribution in time, the licensee adopted the center-peaking scheme recommended by HMR-52. That is, the initiation and peak times of the ssPMP hyetographs for all Hydrologic Engineering Center (HEC)-1 subbasins are assumed to be identical. The NRC staff determined this approach is acceptable as it follows the guidelines provided by NUREG/CR-7046.

The licensee used the FHRR HEC-RAS (River Analysis System) model, which was previously reviewed by the NRC staff, as documented by letter dated September 30, 2016 (ADAMS Accession No. ML16251A281). The differences between the FHRR and MSA models are limited only to inflow boundary conditions and the dam failure scenario. During the audit, the NRC staff requested clarification on whether the licensee could also validate the refined HEC-RAS model for flood stages at the Wylie Reservoir, near the plant site. The licensee responded that it is difficult to validate the stages at the plant site due to the lack of historical flow and stage data. In addition, the data is highly influenced by thoroughly managed upstream discharges and gate openings which follow historically variable operational procedures. As a result, the NRC staff performed additional sensitivity runs as described below to determine the acceptability of the licensee's flood modeling.

~~(CEII)~~ The licensee performed sensitivity runs using the refined HEC-RAS model with potential **[[ ]]** individually to determine which would have the largest flooding impact at the site. As a result, the licensee found the most critical is the **[[**
~~(CEII)~~ **]]**. The licensee added **[[ ]]** for added conservatism and 50 percent of ssPMP to form a combined dam failure scenario as recommended by NUREG/CR-7046. The NRC staff used the same combined dam failure scenario, replacing the licensee's ssPMP with several staff-estimated ssPMP scenarios. The NRC staff's bounding ssPMP scenario includes (1) using a barrier adjustment factor (BAF) instead of an OTF to simulate the impacts of moisture adjustment caused by the terrain during storm transpositioning, and (2) replacing the licensee's storm representative dew point with one generated by the NRC staff for several storms.

For modeling convenience, the NRC staff built a new HEC-HMS model by importing the licensee's HEC-1 input files and reformatting the rainfall input. The NRC staff used version 4.2 of HEC-HMS which is an upgrade to the legacy HEC-1 model. The NRC staff confirmed that the results of the HEC-HMS and HEC-1 simulations for the MSA combined dam failure scenario were nearly identical (i.e., less than about 0.5 percent difference in terms of peak runoff volumes). Using the NRC staff's HEC-HMS model with the licensee's HEC-RAS model, the NRC staff performed the following additional sensitivity analyses to explore how the system of models respond to different input scenarios.

The NRC staff also performed sensitivity runs using HEC-RAS with an assumption of no failure (CEII) of the [[ ]]. For this scenario, the NRC staff used the 1908 storm which is bounding among the licensee's five selected storms. This scenario results in (CEII) the maximum site flood elevation of [[ ]] ft. higher than that of the licensee's scenario, and equal to that of the NRC staff's base scenario (see Table 6).

The NRC staff performed additional sensitivity runs with conservative [[

(CEII)

]]. The NRC staff found the resulting flood elevations for these scenarios to be like the base condition (see Table 7) and determined that these scenarios should not be considered any further.

The NRC staff's bounding ssPMP scenario includes the BAF in place of the OTF, as well as the NRC staff's storm representative dew points in place of the licensee's values. The NRC staff performed sensitivity runs of the H&H models with the staff's BAF ssPMP estimates both with and without the staff's storm representative dew points. As indicated in Table 8, the onsite flood elevations are insensitive to the storm representative dew points used in the NRC staff's ssPMP. The NRC staff's H&H sensitivity runs evaluated alternative spatial distributions for the five selected storm patterns as shown in Figure 2. The NRC staff ran the H&H model with these (CEII) ssPMP results and found water surface elevations increased [[ ]] at the Catawba intake structure. Through a series of sensitivity runs, the NRC staff found that if conservative H&H modeling assumptions were considered, the maximum flood levels at the Catawba site (CEII) could be [[ ]] Although this is with the margin of error for these types of hydrologic and hydraulic modeling, the NRC staff performed a review of the licensee's dam stability analysis as discussed below to check the adequacy of the licensee-postulated combined dam failure scenario.

The licensee updated its wind wave runup analysis using the revised flood elevations, fetch length and average water depth for the bounding scenario. The revised peak flood stillwater (CEII) elevation is [[ ]] at the Catawba Intake, which is the point of interest for the site inundation analysis (see Figure 1). During the audit discussions, the licensee clarified that the contribution from wind-driven wave run-up (i.e., 2-year return period wind speed) was determined using a wave numerical hydrodynamic model, called COULWAVE. Using the COULWAVE model, the licensee simulated the transformation of open-water waves from Lake Wylie propagating to the Catawba Intake under the condition of the bounding combined dam failure scenario. The (CEII) licensee used the incipient surge height of [[ ]] and wave period of 2.9 seconds as input to the model. The licensee considered different combinations of fetch lengths and water depths, and then selected one that produced the most conservative wave height. As a result, the licensee (CEII) obtained the runup height of [[ ]] at the Catawba Intake. Based on the review of the licensee's wave runup estimation, the NRC staff determined that the method and assumptions used to estimate the runup are reasonable. The NRC staff also notes that the licensee's refined runup value is conservative ([[ ]]) when (CEII) compared to the FHRR value.

Given that the total flood elevation at the Catawba Intake exceeds the design basis flood elevation, the licensee evaluated the potential for wave induced inundation along the Lake Wylie shoreline bordering the Catawba site by reviewing shoreline characteristics and the variability in the overtopping water surface time series. To determine the total flood elevations because of the combined effects flood near the power block area, the licensee performed a site flooding re-analysis using the complex 2-Dimensional (2-D) modeling. The licensee analyzed the potential maximum water surface elevation as well as flow paths and elevation hydrographs at various locations throughout the Catawba Yard. From this analysis, the licensee concluded that the inundation from the combined effects flooding would be limited only to the **[[**

(CEII)

]] due to the limited wind-induced wave runup volume. Based on the review of the site topography and plant layout, the NRC staff determined that the licensee's site inundation analysis is reasonable, and the results are acceptable for use. The NRC staff also confirmed that the Lake Wylie Intake structures are not affected by the reevaluated flooding hazard because openings and pump structure are well above the reevaluated flood level at this location.

The licensee stated in its MSA that the refined flooding for the dam failures and their combined effects flood-causing mechanisms would not inundate the Catawba power block and therefore, the associated effects (AEs) and flood event duration (FED) parameters for these flood-causing mechanisms are not applicable. Based on the review of the dam failures and their combined effects flood analyses presented in the MSA and supporting documentation, the NRC staff concludes that the licensee's approach to determine the FED parameters is acceptable for use in the FE. With regards to AEs for dam failures, the NRC staff notes that parameters related to water surface elevations (i.e., stillwater elevation with wind waves and runup effects) were previously reviewed by NRC staff, and were transmitted to the licensee via the ISR letter. Parameters not directly associated with water surface elevation are discussed below and are summarized in Table 3. The NRC staff's review includes the licensee's refined flood elevations and flow velocities relevant to establishing the AE parameters. Based on these reviews, the NRC staff concludes that the licensee's assessment of the AE parameters for dam failures (including combined events) flood-causing mechanism is acceptable for use in the FE.

Limited Intense Precipitation

The design basis LIP event results in a maximum flood elevation of 594.9 ft. at the Unit 1 side of the Yard, and 595.9 ft. at the Unit 2 side of the Yard. The ISR letter for Catawba lists the reevaluated LIP hazard levels as 595.5 ft. at the Unit 1 side of the Yard, and 595.6 ft. at the Unit 2 side of the Yard. The licensee stated, in the FE, that the ISR LIP event was reanalyzed to improve the realism of the flood hazard. The final LIP elevations reported in the FE submittal are 595.2 ft. for Unit 1 side of the Yard, and 595.3 ft. for Unit 2 side of the Yard (both 0.3 ft. lower than the ISR level). Details of the LIP flooding mechanism reanalysis were provided in Attachment A of the FE Enclosure. In its reanalysis, the licensee credits storm drainage at catch basins across the power block. The licensee explained, in the FE, that the (Type I) catch basins have drainage inlets protected by boxed steel grating with four sides and a top. The total open area of this grating was described by the licensee to vary between 4 and 15.6 times the pipe opening, which makes unlikely the complete blockage of this drainage by debris accumulation. The licensee also stated that these catch basins are periodically monitored and cleaned. During the audit, the NRC staff confirmed that these catch basins are the same used for the ISR, the FHRR, the MSA, and the design basis LIP. In its FE, the licensee stated that only 80 of the 87 catch basins at the site were considered in the reevaluation, which the NRC staff saw as conservative because the other 7 basins are expected to catch some of the water from the LIP flood. Also, the licensee stated that the analysis assumed no absorption. The NRC staff considered this assumption as conservative because the soil should reasonably be expected to absorb some of the LIP water. Lastly, the NRC staff confirmed that the volume of water considered in previous LIP evaluations was not revised. Given that the guidance in NEI 16-05 allows for improved realism in the flood model, and that the sources and volume of LIP flooding remained, the NRC staff considers the reanalysis of the LIP to be acceptable for use in the FE.

The details of the LIP reanalysis for Catawba are documented in Calculation CNS-194292-023, "CNS Site Analysis of Local Intense Precipitation," Revision 0. Via the audit process, the NRC staff was able to see the detailed calculations and confirm that it captured the latest hazard information available and that it used the same data bases as those accepted during the FHRR review. The NRC staff also confirmed some of the conservatisms mentioned in the FE (no ground absorption and having only 80 of the 87 catch basins available) are part of the detailed analysis, and consequently contributed to produce conservative water levels.

The NRC staff reviewed the information in the FE regarding the FED parameters evaluated for the flood hazards not bounded by the design basis. The FED parameters for the flood-causing mechanisms not bounded by the design basis are summarized in Table 2. The FED parameters that were reviewed for LIP were warning time or site preparation time, duration of inundation, and period of recession. The maximum inundation duration reported in the FHRR was 5.3 hours. The LIP reanalysis presented in the FE determined a maximum inundation duration of 4.97 hours. The reduction in inundation duration (0.33 hours or approximately 20 minutes) is associated with crediting the basin inlets. After reviewing supporting information associated with the LIP reanalysis, the NRC staff concluded that the reduction of inundation duration for this flooding mechanism is acceptable for use in the FE.

Guidance in NEI 16-05, Revision 1 defines the period of recession for LIP as the period from when floodwaters drop below a penetration or door threshold elevation and drains from the site, to the recession of onsite floodwaters enough to return to the normal plant operation mode. The licensee reported in its FE that recession time for the LIP event is not applicable given that inundation times include water recession from the site. Based on the review of the licensee's LIP reanalysis, the NRC staff concludes that the licensee's period of inundation and recession for the LIP flood-causing mechanism is acceptable for use in the FE.

The licensee also stated in its FE that, at 72 hours prior to the start of rain, Catawba will use a monitoring trigger that consists of a forecast of 4.55 inches (or more) of rain over a 24-hour period using the National Weather Service's Probabilistic Quantitative Precipitation Forecast (PQPF) at the 95th percentile. The FE stated that Catawba Procedure AP/0/A/5500/030, "Plant Flooding," Revision 21, will be revised to reflect this rainfall trigger. The licensee also stated that, if the same forecast remains valid at 12 hours prior to the start of rain, then an action trigger is activated for the site to begin installation of a flood barrier at door AX656B (Unit 2 Electrical Penetration Room door at elevation 594 ft.). The licensee stated in its FE that the preparation time for LIP events is also 12 hours. Given that the monitoring trigger parameters were not changed after the LIP reanalysis, the NRC staff concludes that these are acceptable for use in the FE.

During the FHRR review, the NRC staff confirmed that the licensee's reevaluation of the inundation periods for LIP and associated drainage used present-day methodologies and regulatory guidance. For the FE review, the NRC staff assessed the result from the LIP reanalysis to conclude that the adjustments are consistent with the credit given to the site drainage. Parameters not directly associated with water surface elevation are discussed below and are summarized in Table 3. In its FE, the licensee stated that hydrostatic and hydrodynamic loads resulting from LIP flooding would have a negligible effect on all structures on site and that these are bounded by the design basis tornado wind and missile loads. Moreover, the licensee stated that erosion or sediment deposition are not expected for the LIP flood due to minimal flow velocities. After assessing the information provided during the audit review, the NRC staff agrees with the licensee's conclusions related to these AEs parameters and considers that the resulting AEs are acceptable for use in the FE.

3.2 Evaluation of Flood Impact Assessment for failure of dams and combined events flood (CE/PMF)

3.2.1 Description of Impact of Unbounded Hazards

Based on the hazard refinements, as described above, the licensee stated that even though the revised dam failure flood elevation is [[

(CEII)]] The licensee further stated that even though this flood elevation is [[

(CEII)]], the higher topography adjacent to Lake Wylie prevents the wave run-up from inundating the site in the combined effects PMF event scenario. For this reason, the licensee stated that Catawba is a "dry site" for these flooding mechanisms.

3.2.2 Evaluation of Available Physical Margin and Reliability of Flood Protection Features

Following the refinements done to the CE/PMF and dam failures in the MSA, the licensee reported that the new elevations are still below the yard grade or below higher topography adjacent to Lake Wylie. Based on this information, and the NRC staff's review of these refinements, the staff finds that there is APM and reliable passive protection to the KSFs.

3.2.3 Overall Site Response

The licensee does not rely on any personnel actions or new modifications to the plant to respond to the dam failure and CE/PMF events. As described above, the licensee's evaluation relied on existing passive flood protection features to demonstrate adequate flood protection; therefore, there is no need to review overall site response.

3.3 Evaluation of Flood Impact Assessment for Local Intense Precipitation

3.3.1 Description of Impact of Unbounded Hazard

The licensee stated in its FE that the reanalyzed LIP results in a maximum water surface elevation of 595.2 ft. on the Unit 1 side of the yard (0.3 ft. higher than the Unit 1 design basis food elevation of 594.9 ft.) and 595.3 ft. on the Unit 2 side of the yard (0.6 ft. below the Unit 2 design basis LIP elevation of 595.9 ft.). The licensee stated that, based on the flooding walkdowns associated with the NTTF activities, the site took conservative actions to address gaps surrounding the doors that were larger than expected. These actions were incorporated in CNS Procedure AP/O/A/5500/030, "Plant Flooding." However, the reevaluated LIP hazard level would trigger the need for enhanced protection at door AX656B. The licensee stated in its FE that plant procedures currently specify a sandbag barrier at AX656B, but Duke plans to upgrade to a removable flood barrier that is permanently staged except for selected periods during outages. Section 6.2 of the FE enclosure provides a summary of the proposed modifications and changes. The evaluation of these modifications and changes is provided in Section 3.3.2 of this assessment.

In addition, the licensee stated to have evaluated the effects of water intrusion in the Auxiliary Building (AB), through gaps around doors and to have assessed the volume of water accumulating at lower elevations inside the AB versus the available space. Table 4 of the FE Enclosure provides this comparison. The licensee stated to have evaluated the amount of water that may enter these buildings and the effect it may have over the KSFs. The licensee stated in its FE that there is sufficient space to accommodate the water intrusion and that the KSFs will not be compromised by water intrusion. The NRC staff evaluation of these statements is provided below.

3.3.2 Evaluation of Available Physical Margin and Reliability of Flood Protection Features

The licensee stated in its FE to have assessed the effects of the LIP event at Catawba. One of these effects include the intrusion of water into the AB. For that reason, the licensee evaluated the extent of water intrusion to determine the APM after water accumulation at lower levels of the AB. The licensee concluded that the inundation level and event duration would not allow enough water into the AB to affect the KSFs, except at the Unit 2 Electrical Penetration Room door AX656B at elevation 594 ft. For that reason, the licensee is proposing the installation of a removable flood barrier panel that will remain installed, except during outage periods. Currently, the site flooding procedure calls for the placement of a sandbag barrier at door AX656B. The licensee provided the results of the APM assessment in Table 4 of the FE Enclosure, where the remaining available space after water intrusion was captured.

Using the audit process, performed in accordance with a generic audit plan dated July 18, 2017 (ADAMS Accession No. ML17192A452), the NRC staff audited Duke's evaluation of LIP effects on building internals (CNS Calculation CNC-1206.03-00-0142, "Flooding of Safety Related Structures Due to Excessive Rainfall," Revision 10). Calculation CNC-1206.03-00-0142 includes the detailed evaluation of LIP water intrusion in the AB and the basis for proposing the flood barrier at door AX656B. The NRC staff confirmed that Calculation CNC-1206.03-00-0142 quantifies the amount of water ingress into the spaces identified in Table 4 of the FE Enclosure and that the calculation used the same flood parameters provided in the FE. Calculation CNC-1206.03-00-0142 also describes the impact of internal flooding at all affected doors and provides the logic followed to assess if the water ingress could affect the KSFs.

The NRC staff was able to confirm that the analysis process used to estimate the APM after water intrusion followed a logical process, shows sound engineering judgement, and that it captured the physical characteristics and design of the AB lower spaces where water intrusion might accumulate. In addition, the NRC staff noted that the licensee used conservative assumptions in Calculation CNC-1206.03-00-0142, such as assuming drainage systems inside the AB are unavailable and the use of maximum water flow ingress.

During the audit, the NRC staff requested documents associated with the flood barrier installed at door AX656B. The licensee explained that the flood barrier will be a stackable stop log system, like those used at the exterior emergency diesel generator (DG) access doors. It was also explained that the final selection will be made during the engineering change design phase in the last quarter of 2019. The licensee is tracking this modification, and related activities with the Plant Health Sub-Committee (PHSC) process, under LTAM CN-18-0006, "Flood Barrier for Unit 2 Electrical Penetration Room Door (AX656B)." The licensee also explained that the completion of all planned actions associated with this proposed flood barrier are to be completed no later than two years from effective date of the Mitigation for Beyond-Design-Basis Events (MBDBE) Rule. However, the NRC staff notes that the proposed MBDBE rulemaking described in SECY-16-0142, "Draft Final Rule – Mitigation of Beyond-Design-Basis Events [MBDBE] (RIN 3150-AJ49)," (ADAMS Accession No. ML16291A186), was revised by the Commission in the Affirmation Notice and Staff Requirements Memorandum (SRM) dated January 24, 2019 (ADAMS Accession No. ML19023A038) and removed the generic applicability of mitigating strategies to address the reevaluated hazards. Therefore, the licensee plans to implement the aforementioned actions but not as part of the MBDBE rulemaking process. Given that the licensee currently provides protection to door AX656B with sandbags, the NRC staff finds that there shouldn't be a reduction in safety while actions to install and validate the proposed barrier are completed.

The licensee explained in its FE that the DG building doors and the turbine/service building flood wall are credited as protection against the design basis flood and that for these locations, the LIP event was bounded by the design basis flood. The licensee also explained that below-grade conduits are sealed and should prevent water intrusion. These conduits are qualified to a minimum of 10 pounds per square inch and are subject of preventive maintenance inspections every 18 months. The licensee also explained that the AB roof and penetration seals were inspected as part of the flooding walkdown and that any issues that may restrict outflow of water were corrected. Other details of the flooding walkdown can be found in the NRC Integrated Inspection Report 05000413/2013002, 05000414/2013002 (ADAMS Accession No. ML13115A098).

Based on the above evaluation, the NRC staff concludes that existing margins and protective features provide effective flood protection from the LIP event to maintain KSFs, consistent with Appendix B of NEI 16-05, Revision 1.

3.3.3 Overall Site Response

The licensee stated in its FE that actions will be needed at Catawba to respond to the LIP event. These actions include ensuring that doors are closed and that flood barriers are in position. The licensee stated the need for placing a flood barrier at door AX656B of the Unit 2 Electrical Penetration Room at elevation 594 ft. The licensee explained in its FE that plant procedures currently specify the installation of a sandbag barrier at AX656B, but that Duke plans to upgrade to a removable flood barrier that is in-place always except for selected periods during outages. Other actions identified by the licensee in its FE include changes to the flood response strategy to establish temporary sandbag barriers at AR5 (Waste Shipping Area), AR6 (Hot Machine Shop), and AX658A (Unit 1 Electrical Penetration Room). Similarly, the licensee stated that the MSA identified the need for barriers at door A for the groundwater removal system (WZ) sump pump room. However, the reanalysis of the LIP hazard concluded that, out of all these doors, the only one that needs enhanced protection is door AX656B. The licensee stated that the other sandbag barriers will remain as part of the flood response strategy because these provide defense in depth. However, none of these are credited for the flood response strategy. In addition, the licensee stated in the FE that personnel will be dispatched to monitor and clean debris from catch basins and to monitor selected locations for water accumulation or intrusion.

During the audit process, the NRC staff learned that the licensee will follow the guidance in U.S. Army Corps of Engineers - Northwestern Division, "Sandbagging Techniques," brochure from 2004; and the U.S. Army Corps of Engineers - St. Paul District, "Flood Fight Handbook," from 2016; to prepare and install the sandbag flood barriers. The sandbag barriers will be half-pyramid shaped (3 ft. tall and 4.5 ft. wide), providing approximately 1 ft. of APM. This is documented in a docketed communication between the NRC staff and Duke dated November 11, 2018 (ADAMS Accession No. ML18320A060). In addition, the NRC staff reviewed CNS Procedure AP/O/A/5500/030 to confirm that it includes actions to protect the site against the LIP flood.

The licensee also stated in its FE that calculations were performed to determine the appropriate weather monitoring thresholds for a LIP event. These thresholds are to be incorporated into the appropriate CNS procedure (RP/0/8/5000/030, "Severe Weather Preparations," or AP/O/A/5500/030, "Plant Flooding"). The thresholds are the following: (1) if the T-72 hour PQPF at the 95th percentile calls for 4.55" of rain (or more) over a 24-hour period, meteorological monitoring to support decision making for flood preparation actions will be triggered, and (2) if the PQPF still calls for the 4.55" of rain (or more) within 12 hours of the forecasted storm, then a site-preparation trigger initiates site preparation actions. During the audit, the licensee explained that procedural changes associated with these proposed thresholds are being tracked by the licensee's PHSC process under LTAM CN-18-0006. By adding these thresholds, the site procedures will have updated weather monitoring triggers based on the latest hazard information and methodologies in accordance with NEI 15-05, "Warning Time for Maximum Precipitation Events," dated April 8, 2015 (ADAMS Accession No. ML15104A157).

In addition, as outlined in the MSA, the licensee demonstrated the capability to deploy its FLEX strategies against a postulated beyond-design-basis flooding event and that the FLEX strategies are reasonably protected against the reevaluated flooding hazard. If implemented and maintained as described in the MSA, the FLEX strategies should provide an additional layer of protection against the reevaluated flooding hazard.

4.0 AUDIT REPORT

The July 18, 2017 (ADAMS Accession No. ML17192A452), generic audit plan describes the NRC staff's intention to issue an audit report that summarizes and documents the NRC's regulatory audit of the licensee's FE. This staff assessment serves as the audit report described in the staff's July 18, 2017, letter. Attachment 1 of this report also includes the audit information gathered during the audit review of the MSA. The information in Attachment 1 follows the audit plan in letter dated December 5, 2016 (ADAMS Accession No. ML16259A189) and is specific to the MSA.

CONCLUSION

Based on the information provided by the licensee, the NRC staff concludes that Duke performed the Catawba FE in accordance with the guidance described in NEI 16-05, Revision 1, as endorsed by JLD-ISG-2016-01, and that the licensee has demonstrated that effective protection exists against the reevaluated flood hazards. Furthermore, the NRC staff concludes that Catawba screens out of performing an integrated assessment based on the guidance found in JLD-ISG-2016-01. As such, in accordance with Phase 2 of the process outlined in the 50.54(f) letter, additional regulatory actions associated with the reevaluated flood hazard are not warranted. The licensee has satisfactorily completed providing responses to the 50.54(f) activities associated with the reevaluated flood hazard.

Table 1 - Revised Flood Elevations for Flood-Causing Mechanisms Not Bounded by the Design Basis (from Tables 1 and 2 of Enclosure 1 of the Catawba MSA).

	Flood-Causing Mechanism	Stillwater Elevation (ft. mean sea level (MSL))	Wave Runup (ft.)	Reevaluated Flood Hazard Elevation (ft. MSL)
	Local Intense Precipitation and Associated Drainage [1] - Unit 1 Side of the Yard - Unit 2 side of the Yard	 595.2 595.3	 N.A.[4] N.A.	 595.2 595.3
(CEII)	Dam Failures [2] - Lake Wylie Catawba Intake	[[ ]]	N.A.	[[ ]]
(CEII)	Dam Failures and Combined Effects [3] - Lake Wylie Catawba Intake	[[ ]]	[[ ]]	[[ ]]

Notes:

[1] The LIP flood elevations in the FHRR were revised to support the FE.

(CEII) [2] The refined flood elevation for the dam failures [[ ]].

(CEII) [3] The refined flood elevation for the combined dam failure event [[ ]]

[4] "N.A." stands for not applicable.

Table 2 - Flood Event Durations for Flood-Causing Mechanisms not Bounded by the Design Basis (from Tables 1 and 2 in Enclosure 1 of the Catawba FE).

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	12 hours	4.97 hours[2]	N.A.[3]
Dam Failures [1] - Lake Wylie Catawba Intake	N.A.	N.A.	N.A.
Dam Failures and Combined Effects [1] - Lake Wylie Catawba Intake	N.A.	N.A.	N.A.

Notes:

[1] The FED parameters for the dam failures and their combined effects flood-causing mechanisms are not applicable because the plant site would not be inundated by these flooding mechanisms.

[2] The FHRR Duration of Inundation was revised to support the FE.

[3] "N.A." stands for not applicable.

Table 3 - Associated Effects Parameters not Directly Associated with Total Water Height for Flood-causing Mechanisms not Bounded by the Design Basis (from Tables 1 and 2 in Enclosure 1 of the Catawba MSA).

Associated Effects Parameter	Local Intense Precipitation and Associated Drainage	Dam Failures[1]	Dam Failures and Combined Effects[1]
Hydrodynamic loading at plant grade	N.A.	N.A.[2]	N.A.
Debris loading at plant grade	Minimal	N.A.	N.A.
Sediment loading at plant grade	Minimal	N.A.	N.A.
Sediment deposition and erosion	Minimal	N.A.	N.A.
Concurrent conditions, including adverse weather - Winds	High winds	N.A.	N.A.
Groundwater ingress	N.A.	N.A.	N.A.
Other pertinent factors (e.g., waterborne projectiles)	None	N.A.	N.A.

Notes:

[1] The AE parameters for the streams and rivers, and storm surge flood-causing mechanisms are not applicable because the plant site would not be inundated by these flooding mechanisms.

[2] "N.A." stands for not applicable.

Table 4 - Constant Loss Rates by Infiltration Used in Licensee's HEC-1 model.

Hydrologic Soil Group (HSG)	HSG Description	Constant Loss Rate (CLR) (inch/hour)	
		NRCS Recommended Value	Licensee Selected Value
A	Deep sand, deep loess, and aggregated silts	0.3 ~ 0.45	0.3
A/D	Combination of A and D	n.a.	0.0
B	Shallow loess, sandy loam	0.15 ~ 0.30	0.15
B/D	Combination of B and D	n.a.	0.0
C	Clay loams, shallow loam, soils low in organic content, soils usually high in clay	0.05 ~ 0.15	0.05
C/D	Combination of C and D	n.a.	0.0
D	Soils that swell significantly when wet, heavy plastic clays, certain saline soils	0.00 ~0.05	0.0

Notes:

1. "N.A." stands for not applicable;
2. NRCS (Natural Resources Conservation Service).

Table 5 - **Results of the H&H Model Sensitivity Runs with Different ssPMP Spatial Patterns, Where the Base Condition is the Dam Failures Combined with a Half of Staff's ssPMP.**

	Location	Stillwater Elevations (ft) for Different Spatial Storm Patterns (Storm Types and SPAS ID No.)					
		Tropical 1514	Tropical 1342	Tropical 1299	Tropical 1517	Tropical 1518	General 1299
(CEII)	MNS SNSWP Dam	[[					]]
(CEII)	CNS SNSWP Dam	[[					]]
(CEII)	CNS Intake	[[					]]
(CEII)	CNS Discharge	[[					]]

Notes:

- SPAS (Storm Precipitation Analysis System); MNS (McGuire Nuclear Station); CNS (Catawba Nuclear Station); SNSWP (Standby Nuclear Service Water Pond).
- The licensee reported the maximum water surface elevations at 4 locations: however, the Catawba Intake location is the point of interest for the site inundation analysis.
- HEC-HMS subbasin outflow hydrograph is used as upstream subbasin inflow to channel in HEC-RAS.
- SPAS 1299: Alta Pass, NC/Kingstree, NC storms, July 1916
- SPAS 1342: Mt Mitchell, NC storm, August 1940
- SPAS 1514: Vade Mecum, NC storm, August 1908
- SPAS 1517: Moncure, NC/Settle NC storms, September 1929
- SPAS 1518: Rockingham, NC storm, September 1945

(CEII) **Table 6 - Sensitivity Runs with Staff's ssPMP and [[No Wylie Dam Failure (South Unanchored Section Failure Only)]].**

	Scenario	Maximum Flood Elevation at the Catawba Intake		
		Stillwater Elevation (ft. MSL)	Wave Runup (ft)	Total Flood Elevation (ft. MSL)
~~(CEII)~~	Design Basis	[[		]]
~~(CEII)~~	Base: MSA Combined Dam Failure Scenario (with Duke's ssPMP)	[[		]]
~~(CEII)~~	Base with Staff's SSPMP and SPAS 1514 Pattern	[[( )		]]

~~(CEII)~~ **Table 7 - Sensitivity for [[No Wylie Dam]] Failure Scenario (Use SPAS 1514).**

	Scenario	72-hour ssPMP Depth in Inches with (Storm Type)[1]	Flood Elevation (Stillwater) at Catawba Intake (ft. MSL)	Difference (ft)
~~(CEII)~~	A. Design Basis	n.a.	[[ ]]	-
~~(CEII)~~	B. Base: MSA Combined Dam Failures (Duke SSPMP + [[ ]]	16.6 (General)	[[ ]]	-
~~(CEII)~~	C. Base w/ Staff SSPMP and [[ ]]	20.8 (Tropical) 18.6 (General)	[[ ]] [[ ]]	-
~~(CEII)~~	1. (C) w/ Staff SSPMP + [[ ]]	20.8 (Tropical)	[[ ]]	[[ ]] (1-C)
~~(CEII)~~	2. (C) w/ [[ ]] but Not Bulkhead	20.8 (Tropical)	[[ ]]	[[ ]] (2-C)
~~(CEII)~~	3. (2) w/ Median [[ ]]	20.8 (Tropical)	[[ ]]	[[ ]] (3-C)

Note:

1. This column represents an arithmetic average of 72-hour subbasin ssPMP values within the Wylie basin.

Table 8 - Sensitivity Runs for Different Staff's SSPMP Methods

	Scenario	72-hour SSPMP Depth (inch)	Flood Elevation (Stillwater) at Catawba Intake (ft. MSL)	Difference (ft.)
	A. Design Basis	n.a.	[[ ]]	-
(CEII)	B. Base: MSA Combined Dam Failures (with Duke's ssSPMP)	16.6 (General)	[[ ]]	-
(CEII)	1. (B) w/ Staff ssPMP (BAF + Dew Point, SPAS 1514)	20.8 (Tropical)	[[ ]]	[[ ]] (1-B)
(CEII)	2. (B) w/ Staff ssPMP (BAF, SPAS 1514)	20.2 (Tropical)	[[ ]]	[[ ]] (2-B)
(CEII)	3. (B) w/ Staff ssPMP (BAF, SPAS 1517)	20.2 (Tropical)	[[ ]]	[[ ]] (3-B)

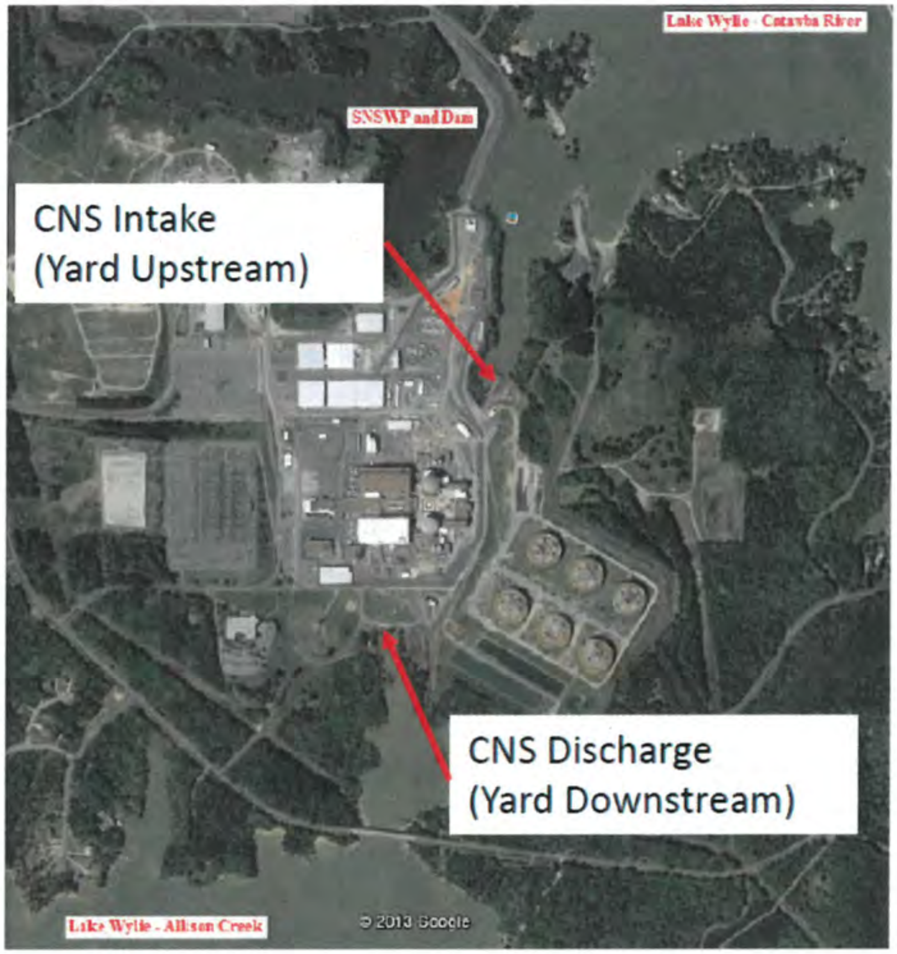

Figure 1 - **Catawba Nuclear Station site layout with key locations for monitoring flood elevations, where the Catawba Intake is the point of interest for the site inundation analysis (Source: Catawba MSA with NRC notations added).**

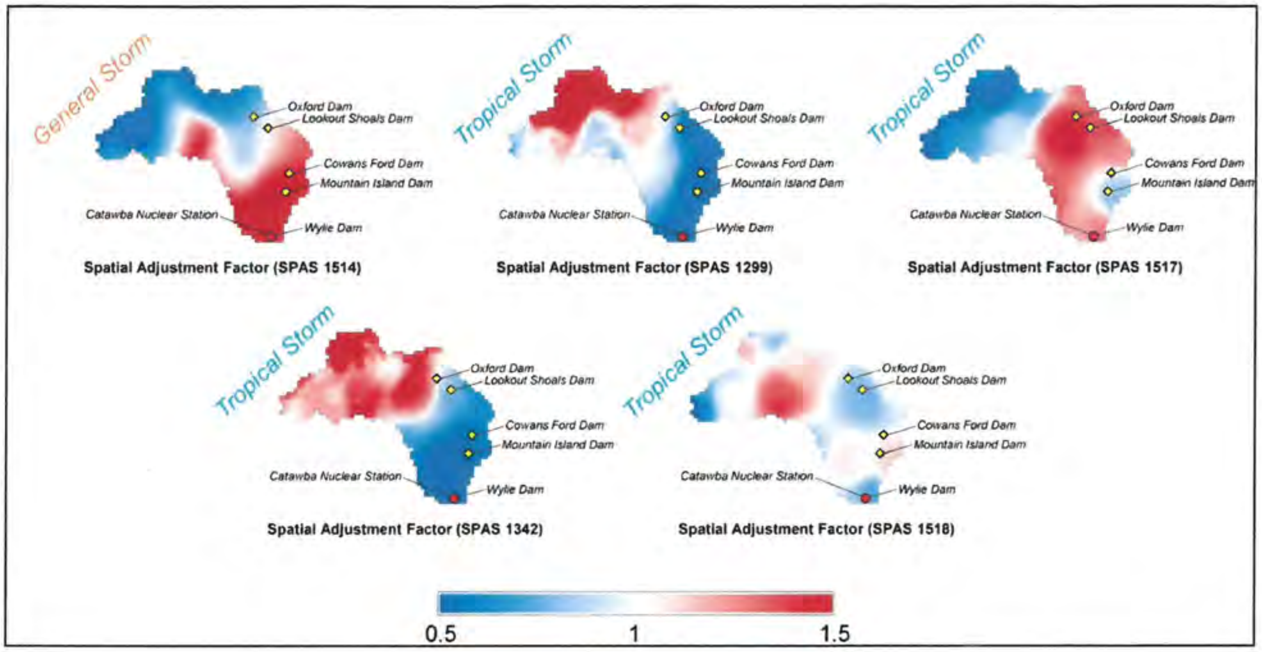

Figure 2 - **Spatial distribution patterns of the NRC staff's ssPMPs for five selected storms used to simulate HEC-HMS.**

Attachment 1
Audit Summary Report for the Catawba MSA Flooding Review

I. Background:

By letter dated December 5, 2016 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML16259A189), the NRC issued a plan describing the intention to conduct an audit related to the MSA. The scope of the audit is listed in the audit plan. The audit allowed the NRC staff to gain additional insights of the information contained in the MSA submittal, such as methodologies used, parameter selection and assumptions, model development and execution, calculations, analyses performed, and supporting documentation. Audits were conducted following the guidance of NRC Office of Nuclear Reactor Regulation, Office Instruction LIC-111, "Regulatory Audits," dated December 29, 2008 (ADAMS Accession No. ML082900195).

II. Logistical Details:

Audit Dates	Audit Location	Audit Participants
8/10/2017; 9/25/2017; 1/25/2018; 5/30/2018; 6/25/2018;	Teleconference Call	*NRC*: Chris Cook, Hosung Ahn, Ken See, Brad Harvey, Kevin Quinlan, Richard Rivera, Juan Uribe and Oak Ridge National Laboratory (NRC Contractor)
7/9-12/2018	HDR Headquarters Charlotte, NC	*Duke*: Greg Robinson, Paul Guill, Sherry Andrews, David Watson, David Best, Stanton Lanham, Darrell Davies, Cecil Fletcher, Bob Pryce, Chris Ey (HDR), Joel Bilodeau (HDR), and Bill Kappel (AWA).

III. Technical Evaluation:

This Attachment contains the technical details regarding the clarifying information requested from Duke, and the corresponding resolution of each item. In addition, each information need requested has been discussed in the corresponding section of this assessment. As part of the audit activities, the licensee made several calculation packages available to the NRC staff via electronic reading room. These calculation packages were only used to expand upon and clarify the information already provided on the docket, and so are not docketed or cited.

IV. Conclusion:

The audit allowed the NRC staff to better understand the Catawba MSA. During its review, the NRC staff did not identify any issues or open items and considers the audit completed and closed.

Catawba MSA Flooding - Audit Summary Report

Info Need		NRC Request	Duke Response (Summary)	NRC Resolution
Set # 1 - August 10, 2017	1	**Site Specific PMP – Main Report and Calculations** The staff requests access to the following background information: • Applied Weather Associates (AWA) site-specific Probable Maximum Precipitation (ssPMP) Main Report for Catawba Nuclear Station: This request is for the complete AWA ssPMP report (including all appendices). • AWA ssPMP Calculation Package for Catawba Nuclear Station: This request is for the complete calculation package for ssPMP calculations used to evaluate riverine flooding (including all appendices).	ssPMP Main report provided	NRC staff and contractors have reviewed the report. This Information reviewed resulted in the issuance of Information Needs #19, 20, and 23. No further information needed.
	2	**Dam Failures and Combined Effects – Calculation Package and Executable Models** Provide staff access to the calculation package that describes the following topics: • ssPMP spatial distribution • Application of Constant Loss Rate (CLR) method • Revised Catawba River Hydraulic (HEC-1) model input and output files, including the verification files. • Revised dam breach modes and parameters • Model revision reevaluated flood scenarios • Revision to wave runup, Seiche, and rapid drawdown of Standby Nuclear Service Water (SNSW) dam	The licensee provided access to the requested calculation packages via Electronic Reading room, and also provided electronic copies of the executable files related to the dam failure and combined effects analyses.	NRC staff and contractors received and reviewed the report. No further information needed.

Set 2 - September 25, 2017	3	**Site Specific PMP – Main Report and Calculations** Provide the Catawba PMP Development Version Log. A version was provided on page C-274 of CNC-1105.00-00-0010; however, it appears the information is not for the Catawba ssPMP.	The licensee provided a copy of the Catawba PMP tool storm database development version log.	NRC staff and contractors received and reviewed the information requested and provided by Duke. No further information needed.
	4	**Site Specific PMP – Complete Storm Analysis Information for all short list storms** Provide access to the analysis information for all short list storms that were used for the Catawba ssPMP calculation. The detailed storm analysis information should include: • Excel files of storm calculation spreadsheets (e.g., Figure 1 on page C-311 of CNC-1105.00-00-0010) • Excel files with SPAS depth-area-duration values and charts (e.g., Figures 2 and 3 on page C-312 of CNC-1105.00-00-0010) • Excel files with storm cumulative mass curve values and charts (e.g., Figure 4 on page C-313 of CNC-1105.00-00-0010)	The licensee provided storm maximization data, including Excel files of (1) storm calculation spreadsheets, (2) SPAS depth-area-duration values and charts, and (3) storm cumulative mass curve values and charts.	NRC staff and contractors received and reviewed the information requested and provided by Duke. The NRC staff's review resulted in the issuance of Information Needs #12, 14, and 17. No further information needed.
	5	**Site Specific PMP – AWA Initial Storm Long List** In addition to the final storm short list, provide an Excel file documenting the complete initial long list storms that have been considered during the development of the Dam Failure and Combined Effects Flooding ssPMPs (used to produce Table 1 on page C-35 of CNC-1105.00-00-0010). If a storm is excluded from the final short list, a brief justification should be provided to identify which long list storms have been previously evaluated by AWA and which have	The licensee provided an Excel file documenting the complete initial long list storms, including providing justification for those storms excluded from the final short list.	NRC staff and contractors received and reviewed the information requested and provided by Duke. The NRC staff's review resulted in the issuance of Information Need #13. No further information needed.

	been newly evaluated as a part of the ssPMP studies.		
6	**Site Specific PMP – AWA Observed Hourly Dew Point Data Sheet for all Short List Storms** For each short list storm, submit an individual spreadsheet documenting the hourly dew point data that were used for storm representative dew point selection (page 8, Section Storm Adjustments, item 2e in AWA PMP Development Workflow Description submitted to NRC on May 7th, 2015). If publicly-accessible dew point data were used (e.g., NCDC ISD), the unique station identifier (e.g., USAF, WBAN, and/or ICAO) and the starting/ending dew point date and hour (used for the calculation of average 12- or 24-hour dew points) should be clearly specified. If the selection of storm representative dew point location deviated significantly from the HYSPLIT trajectories, detailed meteorological reasoning should be provided. If sea surface temperature is used as a surrogate of surface dew point observation, the sea surface temperature observation should be provided. For short list storms for which hourly dew point data were unavailable or not used, provide the relevant data or source information used to determine the storm representative dew point.	The licensee provided an individual spreadsheet documenting the hourly dew point data that were used for storm representative dew point selection for each short list storm.	NRC staff and contractors received and reviewed the information requested and provided by Duke. The NRC staff's review resulted in the issuance of Information Need #18. No further information needed.

7	**Site Specific PMP – AWA Storm Adjustment Factors for all Short List Storms** For each short list storm, provide the final storm adjustment factors used to develop the Dam Failure and Combined Effects Flooding ssPMPs (used to produce Figure 30 on page C-81 of CNC-1105.00-00-0010). The data layers should be in Excel format and include grid-specific values for the following variables: • Storm Name • Longitude and Latitude • Zone • Elevation • IPMF • MTF • OTF • TAF •TRANS	The licensee provided an individual spreadsheet for each short list storm showing the final storm adjustment factors.	NRC staff and contractors received and reviewed the information requested and provided by Duke. The NRC staff's review resulted in the issuance of Information Needs #15, 16, 21, 22. No further information needed.
8	**Site Specific PMP – AWA Dew Point Climatology Data Layers** Provide access to the digital dew point climatology data layers used to develop the Dam Failure and Combined Effects Flooding ssPMPs. The digital dew point climatology GIS data layers (either in Excel or GIS formats) should be provided for the 12- and 24-hour, 100-year recurrence interval dew point climatologies. Provide an Excel file documenting the corresponding monthly dew point climatology values and difference between the observed and gridded values at each gauge used to develop the gridded dew point climatologies.	The licensee provided the digital dew point climatology GIS data layers as well as an Excel file documenting the corresponding monthly dew point climatology values.	NRC staff and contractors have reviewed the information requested and provided by Duke. No further information needed.

9	**Site Specific PMP – AWA Atlas 14 Rainfall Data Layers** Provide the digital Atlas 14 rainfall data layers used to develop the Dam Failure and Combined Effects Flooding ssPMPs. The digital Atlas 14 rainfall data layers (either in Excel or GIS formats) should be provided for the durations (e.g., 24-hour) and for the recurrence intervals (e.g., 10- to 1,000-year) used by AWA and should cover the entire geographic region over which OTF values were derived (i.e., the entire Catawba watershed and all storm centers). A mapped image depicting the Atlas 14 24-hour, 100-year precipitation over this same geographic region should be provided for reference. In addition, for each short list storm, provide the corresponding Atlas 14 rainfall at the storm center location that was used for OTF derivation.	The licensee provided digital Atlas 14 rainfall data layers, including a mapped image depicting the Atlas 14 24-hour, 100-year precipitation, and the corresponding Atlas 14 storm center rainfall for each short list storm.	NRC staff and contractors have reviewed the information requested and provided by Duke. No further information needed.
10	**Site Specific PMP – AWA Probable Maximum Precipitation Data Layers** Provide the final digital ssPMP GIS data layers (used to produce the PMP maps in Appendix A of the AWA ssPMP Main Report, starting on page C-156 of CNC-1105.00-00-0010) developed for the Catawba Nuclear Station Dam Failure and Combined Effects Flooding ssPMPs. The digital ssPMP GIS data layers (either in Excel or GIS formats) should cover the full Catawba watershed for which ssPMP values have been determined and should be provided for all durations and areas analyzed for ssPMP development.	The licensee provided the final digital ssPMP GIS data layers in GIS format.	NRC staff and contractors have reviewed the information requested and provided by Duke. No further information needed.

	11	**Site Specific PMP – ssPMP Tool** Provide the AWA-developed ssPMP ArcGIS Tool (and the associated input files) that can be used to calculate gridded ssPMP depth-area-duration values (see Appendix C of the AWA ssPMP Main Report, starting on page C-267 of CNC-1105.00-00-0010). In addition, provide the 5 spatial distribution factors used to apply PMP for the full Catawba watershed upstream of Wateree Dam (see Appendix D of CNC-1105.00-00-0010).	The licensee provided the AWA ssPMP ArcGIS tool and the 5 spatial distribution factors used to apply PMP for the Catawba watershed.	NRC staff and contractors received and reviewed the information requested and provided by Duke. The NRC staff's review resulted in the issuance of Information Need #24. No further information needed.
Set # 3 - January 25, 2018	12	**Depth Area Duration (DAD) Comparison** The NRC staff identified several short list storms for which large differences exist between the SPAS and USACE/NWS DAD depths as summarized on Tables 1 through 4. A few storms for which large decreases in DAD depths were observed are noted below and require additional justification. Request: Justify the large decreases in DAD depths observed for the four storms selected.	The licensee's response is largely qualitative. Information was provided to justify the differences in historical DAD data from USACE Black Book and HMR 51 vs SPAS-based DAD data. Based on the response, the licensee finds the SPAS analyses to provide improved DAD analyses compared to historical DAD, and for three of the four storms questions, the licensee described that a primary cause for the large differences is the use of different spatial distribution techniques. For the Slide Mtn, NY storm, the primary cause for the large differences found was a difference in the geographic region analyzed (the SPAS-based analysis separated rainfall into 4 storm centers while the HMR analysis analyzed a larger region across New York, Pennsylvania, and New Jersey). During the July 10-12 in-person site visit with the licensee, Duke and NRC (and contractors) discussed technical rationale for separating the Slide Mtn, NY storm into	NRC staff and contractors have reviewed the information provided. To assess the potential impact of using an alternative storm analysis, staff reviewed an alternative SPAS-based analysis for the Slide Mtn, NY storm in which precipitation from all 4 storm centers was combined to form a single DAD. Visual comparison of this full-storm, SPAS-based DAD with the HMR-based DAD found that they were similar, with the SPAS-based DAD being slightly smaller. Staff sensitivity analysis was performed using the HMR-based DAD for the Slide Mtn, NY storm and was found to have no impact on PMP results. Since the full-storm, SPAS-based DAD was smaller than the HMR-based DAD, there would also be no impact on PMP results when using the full-storm, SPAS-based DAD. No further information needed.

		multiple storm centers, with the discussion highlighting that storm center separation is a subjective process requiring professional judgment.	
13	**Storms Long List – Screening** Background: The NRC staff's review of the licensee's initial long list screening file resulted in a few storms being identified as potential PMP drivers; however, the licensee did not include these storms in its ssPMP evaluation. Provide clarification for the removal of the following storms: 1) Mt Pleasant, SC; Westerfield, MA; and Easton, MD. If corrections are warranted, provide updated calculations.	Information was provided to justify the exclusion of these storms. Information included findings from licensee sensitivity analysis, documentation of NWS storm transposition limits, and quantitative comparison of storm DAD against DAD for other, nearby storms.	NRC staff and contractors have reviewed the information requested and provided by Duke. No further information needed.
14	**Short List Screening** Background: Staff's review of the licensee's short storm lists resulted in two Local PMP storms being identified as potential basin-wide PMP drivers; however, these storms were excluded from the General PMP and Tropical PMP analyses. Request: a) Justify the exclusion of the Douglasville, GA and Lafayette, GA storms from the Catawba General PMP analysis. b) Justify the apparent inconsistency in the treatment of transposition limits, as applied to these two storms. c) If corrections are warranted, provide updated calculations.	Information was provided to justify the treatment of these storms as Local rather than general storms, with a primary feature being that inclusion of these storms would not impact the General PMP estimate.	NRC staff and contractors have reviewed the information provided. Staff performed sensitivity analysis to include these storms as General storms and reached the same conclusion as the licensee that consideration of these storms as general storms would not impact the General PMP estimate. No further information needed.

15	**Glennville, GA Storm - Center Location and Elevation.** Background: The licensee's documentation for the Glennville, GA Tropical PMP storm includes inconsistent attribution to which SPAS zone was analyzed, which could affect the adjustment factor calculations for this storm.This storm was separated into two zones by the licensee (1516-1 and 1516-2). The DAD table used by the licensee suggests that SPAS Zone 1 (Glennville, GA, located in the southeastern Georgia) was evaluated in this CNS PMP study. However, the moisture maximization plot and storm center elevation suggested that the center of SPAS Zone 2 (located in the northern Georgia) was used in the calculation. This inconsistency could affect the value of in-place maximization factor (IPMF), moisture transposition factor (MTF), and orographic transposition factor (OTF). Graphical representations of the licensee's analysis are provided in Figure 2. Request: For the Glennville, GA storm,a) Clarify which storm center(s) and elevation was used to produce DAD data using SPAS and to calculate the IPMF and OTF.b) If only one SPAS zone was analyzed, justify why the other storm center was not analyzed.c) If corrections are warranted, provide updated calculations.	The licensee clarified that the storm center location and elevation originally analyzed for this storm were in error and reported a decrease in Tropical PMP when correcting the calculation. When making the correction, the IPMF decreased, the MTF was unchanged, and the OTF was significantly reduced.	The staff finds that the method followed by the licensee to address the error on the storm center location and the corrected results to be reasonable. Therefore, no further information is needed.

16	**Rosman 3 Storm - Center Location and Elevation** Background: The licensee's documentation for the Rosman A3 General PMP storm includes inconsistent attribution to what storm center location and elevation was analyzed, which could affect the adjustment factor calculations for this storm. Request: For the Rosman A3 storm, a) Clarify which storm center and elevation was used to produce DAD data using SPAS and to calculate the IPMF, MTF, and OTF. b) If corrections are warranted, provide updated calculations.	The licensee clarified that the documentation for the Rosman A3 storm included an incorrect storm center latitude and elevation. The licensee states that the calculation used the correct latitude and elevation and that no correction is needed.	NRC staff and contractors have reviewed the information requested and provided by Duke. No further information needed.
17	**Storm Representative Dew Point Comparison with HMR 51** Background: NUREG-0800, Section 2.4.2 (Floods) identifies the HMRs as acceptable sources for PMP estimates. For multiple short list storms, staff identified large differences in the storm representative dew point temperature and IPMF calculated by the licensee versus HMR 51. Differences in the storm representative dew point temperature can affect the adjustment factor calculations for those storms. For the following storms (Wellsboro, PA; Big Meadows, VA; and St. George, GA), justify the large differences between the licensee and HMR storm representative dew points.	Information was provided to justify the large differences between the historical storm representative dew points from HMR 51 and the licensee's values. A primary difference in the two analyses is the use of sea surface temperature vs land-based dew point. In addition, the licensee indicated that the historical HMR analysis evaluated dew point within the rain shadow region for the Wellsboro and Big Meadows storms (which is an inappropriate analysis step) and that the IPMF is nearly equal between the two analyses for the St George storm.	NRC staff and contractors have reviewed the information requested and provided by Duke. No further information needed.

18	**Storm Representative Dew Point Selection: Timeframe and Location** Background: The NRC staff's review of the licensee's storm representative dew point data for short list storms resulted in the identification of several storms for which unreasonable timeframe and/or location data may have been used when selecting the storm representative dew point. This issue can significantly impact PMP values for controlling storms. Request: Provide clarification for the selection of storm representative dew point values for the above storms (Americus, GA; and Douglasville, GA) with respect to timeframe and location selected, especially considering the timeframe of when rainfall occurs at the storm center. If corrections are warranted, provide updated calculations.	For the Americus, GA storm, AWA analyzed data for only 2 stations, rather than 6 stations as documented in the calculation package. Given the updated information, the timeframe analyzed by AWA covers the last 50% of the rainfall event, but the first half of the precipitation is not represented. The 2-station analysis appeared to capture the most intense portion of the storm center rainfall event. During the July 10-12 in-person site visit with the licensee, Duke and NRC (and contractors) reviewed and discussed information related to the Americus, GA storm representative dew point selection. Data were reviewed, and the subjectivity involved in storm representative dew point selection was discussed. The licensee's response revealed that when changing the Douglasville, GA storm representative dew point from 76 deg F to 75 deg F, only the 12-h and 24-h Local PMP were affected.	NRC staff and contractors have reviewed the information provided. The NRC staff sensitivity analysis revealed a 4% increase in the 72-h, 3,017-mi2 Tropical PMP for the Wylie Basin when using a storm representative dew point of 74.5 deg F (computed by staff based on a 6-station analysis with earlier timing) instead of the 76.0 deg F value used by the licensee. Staff sensitivity analysis for the Douglasville, GA storm showed that the storm would not have impacted General PMP either (related to Information Need #14). No further information needed.
19	**Precipitation Frequency Data Source** Background: Section 3.1 of Calculation No. CNS-194292-010, Rev 2 indicates that Technical Paper 40 (TP-40) was used to compute the OTF for five northern storms (which staff assumes would include the five New York storms); however, staff found that the precipitation frequency (PF) depths documented for the five storms in New York match the PF depths from NOAA Atlas 14, Volume 10. Request: Clarify whether the OTF was calculated using TP-40 for any short list storms.	The licensee clarified that TP-40 precipitation frequency data were not used for OTF calculations and that NOAA Atlas 14 Volume 10 data were used instead once they became available. The OTF values for these storms were reported to decrease when switching from TP-40 to NOAA Atlas 14.	NRC staff and contractors have reviewed the information requested and provided by Duke. No further information needed.

20	**Orographic Transposition Factor (OTF) - Methodology Justification** Background: The use of the OTF to adjust observed storm rainfall is a major change from previous HMR methodology and can heavily influence final PMP values. The need for an OTF is not clearly justified by the licensee. a) Justify whether the OTF can be reasonably applied to make the transposition of all storms throughout the Catawba Basin, given the staff approved PMP methodology (see SRP Sections 2.4.2 and 2.4.3) associated with HMR 51 in the Catawba Basin and the lower PMP values which result when excluding the OTF.	The response provides qualitative rationale for using the OTF, including the statement that NOAA Atlas 14 represents the best available data set to utilize in quantifying differences in precipitation processes between two locations within the same transposition region. During the July 10-12 in-person site visit with the licensee, Duke and NRC (and contractors) discussed the use of the OTF. The licensee described the history and evolution of the OTF, which was originally developed by AWA for use in Colorado to primarily capture orographic effects on PMP calculation. The licensee explained that more recent applications of the OTF have described it as a geographic transposition factor which captures spatial variability in precipitation frequency and reflects other meteorological processes besides just orographic. Further discussion with staff included the similarities between the OTF and both mean annual precipitation (MAP) and mean annual maximum (MAM) precipitation. Both MAM and MAP values are associated with high recurrence, non-rare events and are used in NOAA Atlas 14 development as local scaling factors and for spatial smoothing, respectively. Thus, some aspects of NOAA Atlas 14 data (and hence the OTF) largely influence OTF-based PMP depths.	NRC staff and contractors have reviewed the information provided. To assess the potential impact of excluding the OTF, the NRC staff performed an independent analysis in which the OTF was replaced by a barrier adjustment factor (BAF). The BAF approach was used in some HMRs and was in previous AWA-based FHRR ssPMP studies to capture moisture depletion due to barriers. NRC staff's independent analysis when using a BAF calculation approach revealed increases in both General and Tropical PMP depths. The 72-h, 3,017-mi2 PMP for the Wylie Basin was found to be 8% higher when using the BAF instead of the OTF for General PMP and 14% higher when using the BAF instead of the OTF for Tropical PMP. To assess the potential impact of applying staff's BAF-based PMP analysis, the NRC staff performed an H&H sensitivity analysis in which Tropical and General PMP were estimated using a BAF approach, instead of an OTF approach. The Tropical PMP results for Information Need #20 provided a bounding scenario for the staff PMP sensitivity analysis, and were applied to various spatial distributions (per Information Need #24). The resulting H&H sensitivity analysis revealed a maximum increase of 1.5 ft. in peak water surface elevation at the CNS intake compared to the licensee's bounding combined dam failure scenario. No further information needed.

21	**OTF Sensitivity due to Storm Center Location** Background: Staff's review of Orographic Transposition Factor (OTF) application examples reveals large OTF discrepancies for storms with seemingly similar storm centers. These discrepancies could lead to high uncertainty in PMP estimation and raise concern for whether OTF application is reasonable. Request: a) Provide documentation for any sensitivity analyses that were performed to assess alternative storm center locations and the impact on OTF values. b) Justify the large differences in OTF values found for Example 1 and Example 2. c) Justify whether the OTF can be reasonably applied to transposition all storms throughout the Catawba Basin, given the results for Example 1 and Example 2.	The response explains that the large differences in OTF values found for Example 1 and Example 2 are a function of variation in NOAA Atlas 14 precipitation frequency depths at the storm center locations. Additional information is also provided to show how Atlas 14 value change when increasing the storm center used for OTF calculation from a single grid point to larger areas (100 to 10,000 mi2). The results demonstrated some low-to-moderate sensitivity, with areal averaged Atlas 14 precipitation frequency depths varying by as much as 5%. The response confirms that OTF and NOAA Atlas 14 values can be highly variable over short distances.	NRC staff and contractors have reviewed the information provided. This Information Need is related to Information Need #20 and was addressed by staff using the BAF-based SSPMP sensitivity analysis and subsequent H&H sensitivity analysis described for Information Need #20. No further information needed.
22	**OTF 100-y Ratio** Background: For each short list general and tropical storm, the OTF calculation approach used linear regression to estimate the ratio between precipitation frequency (PF) depths for the recurrence interval associated with the storm's maximum point rainfall at 24-h. This approach, which staff believes may provide lower (i.e., less conservative) PMP results, is not the only method which has been used to compute OTF in PMP studies. NRC staff has conducted sensitivity analysis and finds that the 100-year PF ratio provides a more reasonable precipitation adjustment	The response confirms that OTF values can vary widely depending on the calculation approach. The licensee provided sensitivity results when changing the OTF calculation from a linear best fit trendline to a 100-y ratio approach. During the July 10-12 in-person site visit with the licensee, Duke and NRC (and contractors) discussed the OTF calculation approach and licensee's results. During the site visit, the licensee presented H&H sensitivity analysis results when applying a revised OTF calculation using the 100-y ratio approach. The licensee	NRC staff and contractors have reviewed the information provided. Staff performed independent analysis in which the OTF was calculated using the 100-y ratio in NOAA Atlas 14 precipitation frequency depths. Staff independent analysis using the revised 100-year OTF approach revealed significant increases in both General and Tropical PMP depths. The 72-h, 3,017-mi2 PMP for the Wylie Basin was found to be 11% higher when using the 100-y ratio approach instead of the linear best fit trendline approach for General PMP and 7% higher when using the 100-y ratio approach instead of the linear best fit trendline approach for Tropical PMP.

	approach than the regression approach. For example, by using the 100-year ratio, the final OTF values maintain the same spatial patterns as found in the NOAA Atlas 14 PF depth maps. When using the linear regression approach, variability is introduced by differences in the slope and intercept of the fitted relationship from grid to grid. This variability does not have a physical basis. a) Justify the calculation of OTF using linear regression instead of the 100-year ratio.	demonstrated that the changes in WSE at the site are insignificant.	The NRC staff's ssPMP sensitivity analysis found that the 100-y ratio approach produces lower SSPMP depths than the BAF approach. No further information needed.
23	**OTF Lower Limit** Background: The licensee's OTF applications have enforced an upper limit of 1.5 but no lower limit. The lack of a lower limit may not be justified and may underestimate PMP in some cases. Request: Justify the exclusion of a lower limit for the OTF, or consider using a reasonable OTF lower limit.	The response shows no impact when implementing an OTF lower limit of 0.67. This finding is also confirmed by the NRC staff sensitivity analysis. Additional discussion in the response includes rationale for including a +/- 50% difference in OTF as upper and lower caps (i.e., use of 0.5 as a lower limit and 1.5 as an upper limit).	NRC staff and contractors have reviewed the information requested and provided by Duke. The NRC staff's sensitivity analysis confirmed the licensee's conclusion that there is no impact on the PMP when implementing an OTF lower limit of 0.67. No further information needed.

24	**PMP Spatial and Temporal Distribution** Background: The alternative SSPMP spatial distributions used by the licensee are limited to 5 historical rainfall events over the Catawba basin (i.e., 1908, 1916, 1929, 1940, 1945 events). The selection of a limited number of spatial distribution patterns without considering the pattern of the spatial PMP distribution is not clearly justified, and it is not clear that the selected spatial PMP distributions provide reasonably conservative PMF results. It is also not clear what PMP temporal distribution was used in the licensee's evaluation. Table 19 of Calculation No. CNS-194292-010, Rev 2 shows some example PMF results for the different PMP spatial distributions. Based on the variability in peak water levels at Cowans Ford and Wylie Dams resulting from the different scenarios, it is not clear that the five PMP spatial distributions evaluated provide reasonably conservative PMF results. Request: a) Justify the selection of PMP spatial distributions considering the broader range of physically possible PMP spatial distribution scenarios. b) Demonstrate that the PMP spatial distributions considered result in reasonable PMF results given the sensitivity in peak water levels found in Table 19 of Calculation CNS-194292-010, Rev 2. c) Provide PMF sensitivity analysis results when applying the standard PMP isohyetal pattern from HMR 52. Variation in the storm orientation and positioning should be considered. d) Clarify what PMP temporal distribution was	During the audit, Duke and NRC (including contractors) discussed the spatial and temporal distributions used to evaluate PMP for the Catawba Basin. Information presented included an overview of the spatial distributions considered, including why they were used, how they were derived, and how they were applied. Of the five historical storms used to develop spatial distributions, one was a general storm and four were tropical storms. For application, the General PMP was applied using the one general storm spatial distribution, and the Tropical PMP was applied using the four tropical storm spatial distributions. Further discussion included discussion of critical locations within the watershed (i.e., upstream dams) and implications of applying General and Tropical PMP using all five spatial distributions. The licensee stated that the Tropical PMP (which is higher than the General PMP) could be reasonably applied to the general storm spatial distribution, and vice versa. The licensee's calculation, however, did not consider the use of both Tropical and General PMP to all five spatial distributions. Further discussion included staff's observation that the PMP depths applied to specific sub-basins could result in much higher local precipitation volume than supported by the original PMP calculation (i.e., spatially distributed PMP can vary widely from the OTF-based PMP). Staff also noted that the five spatial	NRC staff and contractors have reviewed the information provided. To support review, staff completed a series of sensitivity analyses in which gridded PMP sensitivity analysis estimates were spatially distributed according to the five different storm-based spatial distributions. These analyses included applying both General and Tropical PMP estimates across all five spatial distributions. To assess the potential impact of applying the Tropical PMP using various spatial distributions (including the one general storm spatial distribution), the staff performed H&H sensitivity analyses in which the SPAS 1514 and SPAS 1517 Wylie spatial distributions were applied to the Tropical PMP resulting from staff's BAF sensitivity analysis (see Information Need #20). The results of those analyses are described in "Staff's Resolution" for Information Need #20. As the licensee used center peaking distribution of SSPMP in time followed by the guideline provided by NUREG/CR-7046 (NRC, 2011), the staff determined this practice is also acceptable. No further information needed.

		applied, and provide justification for the selection.	distributions provide a fairly wide range of spatial variability.	

25	**2016 SSPMF CLR Model** Background:The Calculation CNS-194292-010 Revision 2 indicates that the licensee used the 2016 Site-specific probable maximum flood (SSPMF) Constant Loss Rate (CLR) Model to simulate river basin outflows for the postulated PMF and dam failure scenarios. The 2016 SSPMF CLR Model, which is based on a legacy HEC-1 model, uses site-specific probable maximum precipitation (SSPMP) as hydrologic input and the CLR method as an infiltration estimation algorithm. Request: The staff requests the licensee to submit the Microsoft Access 2010 database mentioned in CNS-194292-010 Revision 2, Appendix E, Sec 3.1. The staff also requests access to the '2016 SSPMF CLR Model' (e.g., HEC-1 files) and '2016 Catawba River Model' (HEC-RAS) mentioned in the Calculation CNS-194292-010 Revision 2, Appendix E related to simulating the following scenarios: • Constant Loss Rate Sensitivity runs with HEC-1 in Section 3 • Storm Sensitivity runs with HEC-1 discussed in Section 4 • SSPMF scenarios with HEC-RAS discussed in Section 5 • Combined effects seismic dam failure events with HEC-RAS discussed in Section 6.	The information requested was provided.	The NRC staff has reviewed the requested information and considers the response reasonable. No further information needed.

	26	**2016 Catawba River Model** Background: The Calculation CNS-194292-010 Revision 2 indicates that the licensee used the 2016 Catawba River Model to simulate river flood levels for postulated riverine PMF and dam failure scenarios. The 2016 Catawba River Model is an updated version of the HEC-RAS-based 2013 Catawba River Model used in the FHRR. The 2016 Catawba River Model uses the inflow hydrographs simulated from the 2016 SSPMF CLR Model. Request: The staff requests the licensee to submit electronic version of input and output files (e.g., HEC-RAS files) for the 2016 Catawba River Model for simulating the scenarios mentioned in Calculation CNS-194292-010 Revision 2: • Verification scenarios as mentioned in Calculation Section 4.3. • Catawba River Model verification runs in Calculation Table 25. • Catawba River Model scenarios in Calculation Section 5.8 (except ones already requested by Information Need #25).	The licensee provided the requested information.	NRC staff and contractors have reviewed the information provided and considers the response to be reasonable. No further information needed.
Set # 4 - May 30, 2018	1	Describe how the distribution of the ssPMP in space and time was performed	Refer to the licensee's response for Information Need number 25.	During the audit, the licensee provided additional clarification on the ssPMP spatial and temporal distributions as part of Information Needs number 24 and 25. Based on the additional discussions during the audit, the NRC considers the response is reasonable. No further information needed.

2	Describe how were the meteorological and hydrological characteristics of severe storms in this region considered when distributing the ssPMP.	Refer to the licensee's response for Information Need number 25. ~~(CEII)~~	During the audit, the licensee provided additional explanations on this issue as part of Information Needs number 24 and 25. The licensee also clarify that they used the spatial pattern of 5 historical storm without considering to move storm centers to other locations (e.g., to the basin center to have higher basin runoffs). As a confirmatory analysis, the staff reviewed the pattern of the licensee-selected 5 storms and found these 5 storms represent well the spatial variability of potential severe storms for the basin. The staff also performed confirmatory runs of H&H models with the 5 selected storm patterns and found the spatial patterns are relatively insensitive to simulated flood elevations at the Catawba site [[(.]] Based on the additional discussions during the audit, the NRC considers the response is reasonable. No further information needed.
3			
3.a	**Adequacy of the number and size of sub-basins** ~~(CEII)~~ The number of sub-basins changed from [[ ]] sub-basins in DAMBRK NRC Staff request that calibration/validation of the H&H models be discussed at the upcoming audit, including the following items: i. (ERR Feedback, p. 6): The licensee states the Catawba River HEC-RAS Model was calibrated to the DAMBRK model by adjusting inflow hydrographs for 47 subbasins, such that the superposition of the routed hydrographs	The discussion clarified the number of sub-basins and the hydraulic and hydrologic modeling assumptions. As part of the response, the staff requested a sensitivity of the CLR analysis for the middle/lower part of the basin which validated the results obtained for the upper part of the basin. The discussions also demonstrated that the adjusted sub-basin inflows based on the DAMBRK model are inconsequential to the estimated flood elevations obtained at the site.	Based on the additional discussions during the audit, the NRC considers the response is reasonable. No further information needed.

	reasonably matches the DAMBRK results. The staff identified a potential error in defining the subbasin areas used to simulate inflow hydrographs for the HEC-RAS modeling, and also some discrepancies in the total of subbasin inflows. The staff requests the licensee discuss resolution of this issue by either (a) discussing their correction to the subbasin areas and the resulting inflow discrepancies; or (b) demonstrating that these issues are inconsequential to the estimation of the flood elevations in the Catawba site.		
	Adequacy of the number and size of sub-basins ii. The licensee stated during the audit that the CLR change has only a small impact on the results at the site. The NRC staff noted from Calculation 010, Table 15 that the CLR potentially underestimates about **[[** ~~(CEII)~~]] decrease of the Wylie reservoir water level, which may indicate that the change caused by switching infiltration from CN to CLR meaningfully impacts the results.	The discussion clarified the number of sub-basins and the hydraulic and hydrologic modeling assumptions. The licensee clarify that it is practically impossible to calibrate the CLR parameters for the Catawba basin because historical flow data are not readily available. To cope with the calibration/verification issue, they said they followed the guidelines method conservatively.	Based on the additional discussions during the audit, the NRC considers the response is reasonable. No further information needed.
3.b	Provide additional clarification regarding the verification of constant loss rate in each sub-basin	Refer to the licensee's response for Information Need number 3.a	Refer to NRC's resolution for Information Need number 3.a
3.c	Provide additional clarification regarding the sub-basin characteristics and rainfall distributions in DAMBRK, as well as calibration for historical storm events	The licensee stated that the DAMBRK software was not utilized. The analysis of dam breach modeling was done utilizing HEC-RAS. The number and size of sub-basins have not changed in the revised analysis that was documented in Enclosure 2 of the MSA submittal. The	Based on the additional discussions during the audit, the NRC considers the response is reasonable. No further information is needed.

		description of rainfall distributions evaluated and applied is covered in responses to Information Needs 24 & 25	
3.d	Provide additional clarification regarding the consideration of short-term return flows from infiltration by high constant loss rate	The verification process did not change in the revised analysis that was documented in Enclosure 2 of the MSA submittal. Accordingly, Duke contends that a response considering this factor is not needed.	Based on the additional discussions during the audit, the NRC considers the response is reasonable. No further information is needed.
3.e	Provide additional clarification regarding the matching historical peak and time to peak of discharge/stage for different storm events at, or near the Catawba Nuclear Plant site	Same process was used in the analysis supporting the original FHRR, and this has not changed in the revised analysis that was documented in Enclosure 2 of the MSA submittal. Accordingly, Duke contends that a response considering this factor is not needed.	Based on the additional discussions during the audit, the NRC considers the response is reasonable. No further information is needed.
3.f	Provide additional clarification regarding the calibration of model parameters, including constant loss rates and lag times in HEC-1, and sub-basin parameters for DAMBRK	HEC-1 was utilized for the hydrology, not DAMBRK. The verification process on infiltration rates has not changed from the original analysis that was documented in Enclosure 2 of the MSA submittal.	Based on the additional discussions during the audit, the NRC considers the response is reasonable. No further information is needed.
3.g	Provide additional clarification regarding the use of the up-to-date version of models (e.g., HEC-HMS 4.2, HEC-RAS 5.0) compared to older versions (e.g., HEC-1, DAMBRK)	The same version of the models that were used for the FHRR were used for re-analysis documented in Enclosure 2 of the MSA submittal. Accordingly, Duke contends that a response considering this factor is not needed.	Based on the additional discussions during the audit, the NRC considers the response is reasonable. No further information is needed.

4			
4.a	**Use of a half of PMP instead of a half of PMF for the combined dam failure scenarios** In relation to the licensee's H&H modeling, the staff noted potential variations from the current NRC guidance (e.g., NUREC/CR-7046, JLD-ISG-2013-1, etc.) relating to initial reservoir condition before dam breach, 5% spillway capacity reduction, nonlinear adjustment for unit hydrograph, use of ½ PMP instead of ½ PMF, and new version of models. NRC staff have determined these to be of lessor impact than the following. However, NRC staff would like to confirm these values and their selections in the H&H models and their potential cumulative effects on the water level at the CNS site in regarding to the following items i thru iii below. Staff would like to discuss the following items during the audit: i. Section 4.2 of Calculation CNS-194292-010 Rev. 2, states the HEC-RAS model assumes that hydro plants are removed from service when the flood tailwater elevation of each plant exceeds the substation yard elevation. However, Table 5 on p. 106 indicates spillway discharge is based only on headwater. Please clarify this discrepancy.	Item i: The licensee clarified that the discharge rating curves for major Catawba Development Projects used in the HEC-RAS model were constructed using the relation of both the tailwater and headwater.	Based on the additional discussions during the audit, the NRC considers the response is reasonable. The NRC staff now better understands the licensee's modeling assumptions related to the discharge rating curves. No further information is needed.

ii. In relation to the postulated dam breach scenario, it is unclear whether the licensee updated the FHRR Calculation package CNC-194292-015 related to the Wylie dam stability analysis to account for the decreased flood levels associated with the MSA conditions.	The licensee clarified (based on the results of HEC-RAS simulation) that the South embankment overtopped but did not fail given that the overtopping elevation [[~~(CEII)~~]] for the postulated H.2 event (i.e., the combined seismic dam failure with 1/2 of PMF scenario). For the Wylie bulkhead stability analysis, the staff requested that the licensee provide the results of additional sensitivity runs for the bulkhead stability analysis with different friction parameters and water level conditions. The licensee informed that an alternate approach could be reviewed. Instead, the licensee provided additional FERC-approved documentation approving and certifying their stability analysis. The staff reviewed the licensee provided documents during the audit: (1) Calculation CNS-194292-015 for Bulkhead stability analysis; (2) the Wylie Hydro Site Investigation Concrete Gravity Structure Stability Analysis; and (3) the Wylie developed supporting technical documentation.	The two documents were reviewed and approved by FERC. The NRC staff's review included a summary of the drilling and boring samples performed, geologic considerations, construction drawings, etc. Based on the information provided, the staff confirmed that the licensee used the FERC-accepted parameters in the bulkhead stability analysis for the MSA. Based on the review of the documentation provided by the licensee, the NRC staff agrees that the information supports the licensee's assumptions regarding the failure of the unanchored south bulkhead section (as a monolith section) under the revised flooding conditions presented in the MSA. Therefore, the NRC staff no longer considers that the additional sensitivity analysis related to the dam stability analysis by the licensee warranted. No further information is needed.
iii. Sec. 5.2.4, Table 7 indicates the HEC-RAS-based reservoir storage volumes for CF and ~~(CEII)~~ Wylie are approximately [[ ]] than those of respective bathymetry-based volumes, resulting in potential underestimation of reservoir stages. Staff would like to discuss the impacts of this volume calculation during the audit.	The licensee stated that the discrepancies in the reservoir storage volumes between the HEC-RAS based and bathymetry-based storage estimates would not significantly change the estimated flood elevation at the site.	The staff determined that the licensee's clarifications are acceptable. No further information is needed.

	4.b	Use of the FERC Target Reservation Elevation as an initial condition, instead of using the normal maximum reservoir elevation (as guided by NRC NUREG/CR-7046, JLD-ISG-2013-01)	The licensee clarified that this has not changed (from the analysis supporting the FHRR) in the revised analysis as documented in Enclosure 2 of the MSA submittal.	The staff determined that the licensee's clarifications are acceptable. No further information is needed.
	4.c	Sensitivity runs from the selected controlling (optimal) scenario versus runs for low flood levels:	The licensee clarified that they used a graded approach to develop the H&H model and thus for the sensitivity analyses.	The staff determined that the licensee's clarifications are acceptable. No further information is needed.
	4.d	Clarify how the runup of ~~(CEII)~~ [[ ]]	The licensee stated that the contribution from wind-driven wave run-up (i.e., 2-year return period wind speed) was determined using a wave numerical hydrodynamic model, called COULWAVE. Using the COULWAVE model, they simulated the transformation of open-water waves from Lake Wylie propagating to the Catawba Intake under the condition of the bounding combined dam failure scenario.	The staff reviewed the estimation of the runup related to the bounding combined dam failure flooding, and determined the licensee's approach is acceptable. No further information is needed.
Set # 5 - June 25, 2018	1	**Implementation of FLEX – Reevaluated LIP** The MSA states on Section 3.5 that flood barriers were determined to be necessary for the outside lower edge of doors AX656B and AX658A. Regarding the protection of these doors, please: • Provide a physical description of the type of flood barrier that is being used, including dimensions. The description should confirm that the barrier has sufficient margin such that it is acceptable for use against the higher reevaluated hazard (0.6' delta). • Provide a description of the estimated amount of time needed to deploy and setup the flood barriers. The description should confirm that the warning time deployment trigger of 12 hours is adequate. • If available, any pictures of the barriers	The licensee provided a summary of the revised strategy as described in Section 3.3.1 of this staff assessment, and docketed by letter dated November 11, 2018 (ADAMS Accession No. ML18320A060).	The NRC staff reviewed the proposed strategy, as revised during the audit, and considers it an acceptable approach. Given that the strategy selected during the audit differs from the one described in the MSA, the licensee's response has been placed on the docket for completeness of information. No further information is needed.

	installed and/or the staging area outside the Unit 1 and Unit 2 Auxiliary Buildings would be helpful in the response.		
2	**Implementation of FLEX – Reevaluated LIP** The MSA states on Section 6.2.2.7 that the LIP event coincident with an ELAP may cause the two groundwater drainage system (WZ) pumps (A and B pumps) to fail. Request: • Provide a physical description of the type of flood barrier that is being used, including dimensions. • Provide a description of the estimated amount of time needed to deploy and setup the flood barriers. The description should confirm that the warning time deployment trigger of 12 hours is adequate. • Identify whether any of the proposed door barriers will inhibit personnel access or deployment of the FLEX TDAFW sump pumps (or alternate portable pumps) and the associated portable diesel generators that power these pumps. • If available, any pictures of the barriers installed and/or the staging area outside the 7780 Building would be helpful in the response.	The licensee provided a summary of the revised strategy as described in Section 3.3.1 of this staff assessment and docketed by letter dated November 11, 2018 (ADAMS Accession No. ML18320A060).	The NRC staff reviewed the proposed strategy, as revised during the audit, and considers it an acceptable approach. Given that the strategy selected during the audit differs from the one described in the MSA, the licensee's response has been placed on the docket for completeness of information. No further information is needed.

3	**Implementation of FLEX – Reevaluated LIP** The MSA states on Section 6.5 that FLEX strategies will be modified in order to address the unbounded LIP mechanism. These actions include: • Evaluation of the flood barriers in accordance with the guidance of NEI 12-06, Appendix G and the revision of flooding related procedures. • Revision of plant procedures to address the warning time. • Validate plant procedures in accordance with the guidance of NEI 12-06, Appendix E. Please provide an estimated completion schedule of the proposed activities.	The licensee provided a summary of the revised strategy as described in Section 3.3.1 of this staff assessment and docketed by letter dated November 11, 2018 (ADAMS Accession No. ML18320A060).	The NRC staff reviewed the proposed strategy, as revised during the audit, and considers it an acceptable approach. Given that the strategy selected during the audit differs from the one described in the MSA, the licensee's response has been placed on the docket for completeness of information. No further information is needed.

SUBJECT: CATAWBA NUCLEAR STATION, UNITS 1 AND 2 – STAFF ASSESSMENT OF FLOODING FOCUSED EVALUATION (EPID NO. L-2018-JLD-0178) DATED May 3, 2019

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