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

May 18, 2017

Mr. Bryan C. Hanson
President and Chief
Nuclear Officer
Exelon Nuclear
4300 Winfield Road
Warrenville, IL 60555

SUBJECT: OYSTER CREEK NUCLEAR GENERATING STATION – FLOOD HAZARD MITIGATION STRATEGIES ASSESSMENT (CAC NO. MF7953)

Dear Mr. Hanson:

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, pursuant to Title 10 of the *Code of Federal Regulations* (10 CFR), Section 50.54(f), "Conditions of Licenses" (hereafter referred to as the "50.54(f) letter"). The request was issued in connection with implementing lessons learned from the 2011 accident at the Fukushima Dai-ichi nuclear power plant, as documented in the NRC's Near-Term Task Force (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). Concurrent with the reevaluation of flood hazards, licensees were required to develop and implement mitigating strategies in accordance with NRC Order EA-12-049, "Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events" (ADAMS Accession No. ML12054A735). In order to proceed with implementation of Order EA-12-049, licensees used the current licensing basis flood hazard or the most recent flood hazard information, which may not be based on present-day methodologies and guidance, in the development of their mitigating strategies.

By letter dated December 16, 2016 (ADAMS Accession No. ML16351A219), Exelon Generation Company, LLC (the licensee) submitted the mitigation strategies assessment (MSA) for Oyster Creek Nuclear Generating Station (Oyster Creek). The MSAs are intended to confirm that licensees have adequately addressed the reevaluated flooding hazards within their mitigating strategies for beyond-design-basis external events. The purpose of this letter is to provide the NRC's assessment of the Oyster Creek MSA.

The NRC staff has concluded that the Oyster Creek MSA was performed consistent with the guidance described in Appendix G of Nuclear Energy Institute 12-06, Revision 2, as endorsed by Japan Lessons-Learned Division (JLD) interim staff guidance (ISG) JLD-ISG-2012-01, Revision 1, and that the licensee has demonstrated that the mitigation strategies are reasonably protected from reevaluated flood hazards conditions for beyond-design-basis external events. This closes out the NRC's efforts associated with CAC No. MF7953.

If you have any questions, please contact me at 301-415-6197 or at Tekia.Govan@nrc.gov.

Sincerely,

Tekia V. Govan

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

Enclosure:
Staff Assessment Related to the
Mitigating Strategies for Oyster Creek

Docket No. 50-219

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STAFF ASSESSMENT BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATED TO MITIGATION STRATEGIES FOR

OYSTER CREEK NUCLEAR GENERATING STATION

AS A RESULT OF THE REEVALUATED FLOODING HAZARD NEAR-TERM TASK FORCE

RECOMMENDATION 2.1- FLOODING

CAC NO. MF7953

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, pursuant to 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).

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The NRC staff and industry recognized the difficulty in developing and implementing mitigating strategies before completing the reevaluation of flood hazards. The NRC staff described this issue and provided recommendations to the Commission on integrating these related activities in COMSECY-14-0037, "Integration of Mitigating Strategies for Beyond-Design-Basis External Events and the Reevaluation of Flood Hazards," dated November 21, 2014 (ADAMS Accession No. ML14309A256). The Commission issued a staff requirements memorandum on March 30, 2015 (ADAMS Accession No. ML15089A236), affirming that the Commission expects licensees for operating nuclear power plants to address the reevaluated flood hazards, which are considered beyond-design-basis external events, within their mitigating strategies.

Enclosure

Nuclear Energy Institute (NEI) 12-06, Revision 2, "Diverse and Flexible Coping Strategies (FLEX) Implementation Guide" (ADAMS Accession No. ML16005A625), has been endorsed by the NRC as an appropriate methodology for licensees to perform assessments of the mitigating strategies against the reevaluated flood hazards developed in response to the March 12, 2012, 50.54(f) letter. The guidance in NEI 12-06, Revision 2, and Appendix G in particular, supports the proposed Mitigation of Beyond-Design-Basis Events rulemaking. The NRC's endorsement of NEI 12-06, including exceptions, clarifications, and additions, is described in NRC Japan Lessons-Learned Division (JLD) interim staff guidance (ISG) JLD-ISG-2012-01, Revision 1, "Compliance with Order EA-12-049, Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events" (ADAMS Accession No. ML15357A163). Therefore, Appendix G of NEI 12-06, Revision 2, describes acceptable methods for demonstrating that the reevaluated flooding hazard is addressed within the Oyster Creek Nuclear Generating Station (Oyster Creek) mitigating strategies for beyond-design-basis external events.

2.0 BACKGROUND

By letter dated February 9, 2016 (ADAMS Accession No. ML16035A265), the NRC issued an interim staff response (ISR) letter for Oyster Creek. The ISR letter provided the reevaluated flood hazard mechanisms that exceeded the current design basis (CDB) for Oyster Creek and parameters that are a suitable input for the mitigating strategies assessment (MSA). For Oyster Creek, the mechanism listed as not bounded by the CDB in the ISR letter are local intense precipitation (LIP) and probable maximum storm surge (PMSS). By letter dated December 16, 2016 (ADAMS Accession No. ML16351A219), Exelon Generation Company, LLC (the licensee) submitted the Oyster Creek MSA for review by the NRC staff.

3.0 TECHNICAL EVALUATION

3.1 Evaluation of Oyster Creek's Current FLEX Strategies

The licensee documented in the Oyster Creek MSA that they performed an assessment that concluded the current FLEX strategies for Oyster Creek can be successfully implemented for the PMSS flood (with wind-wave runup) values listed in the ISR letter without modification. In addition, with the procedural changes to incorporate sandbag protection and associated warning time, the current FLEX strategies for Oyster Creek can be successfully implemented for the LIP flood value listed in the ISR letter without further modification.

Specifically at the Oyster Creek site, during the onset of an extended loss of alternating current power (ELAP), the reactor is assumed to trip from full power. The main condenser becomes unavailable due to the automatic closure of the main steam isolation valves.

During Phase 1, feedwater flow to the reactor is lost and the electromagnetic relief valves automatically cycle to control pressure, causing reactor water level to decrease. Decay heat is initially removed by two isolation condensers (ICs). The IC valves open automatically and steam from the reactor pressure vessel is cooled and condensed in the IC. The steam from the reactor pressure vessel (RPV) condenses in the tube side of the IC and flows back to the RPV via natural circulation. The installed ICs provide core cooling and depressurization during the initial phase and within 100 minutes of the ELAP, the licensee expects to establish makeup to the shell side of the ICs using a diesel driven FLEX pump during Phase 2. This time frame will ensure that the condenser tubes remain covered to maintain decay heat removal. The FLEX pump continues to provide makeup water to the ICs as needed to continue reactor cooling as well as depressurization which limits system leakage, thus reducing containment heatup. When the RPV pressure is sufficiently reduced, the FLEX pump provides injection into the RPV for cooling, depressurization, and inventory control. The diesel driven FLEX pump takes water from the intake structure, which is supplied from Barnegat Bay (the ultimate heat sink (UHS) for the plant). The water from the UHS will be used to supply the shell side of the two ICs for an indefinite period of decay heat removal, provide makeup water to the RPV.

During Phase 1, in order to extend the safety-related battery life, the operators will complete the bus load stripping within the initial 90 minutes following the ELAP event. During Phase 2, a 500-kilowatt (kW), 480 volt alternating current (Vac) FLEX generator will be deployed from a FLEX storage pad and will enable re-energizing existing station battery chargers and vital instrumentation within 2.5 hrs, which is well inside the battery coping times with or without the load shed.

During Phase 3, a National SAFER [Strategic Alliance for FLEX Emergency Response] Response Center (NSRC) will provide high capacity pumps and large diesel-driven generators, which could be used to as backup to the FLEX equipment used in Phase 2.

3.1.1 Probable Maximum Storm Surge

Although the FLEX design-basis incorporated the ISR letter flood values for the PMSS event, the NRC staff noted that the licensee still performed an assessment consistent with Section G.4.1 of NEI 12-06 for the PMSS event. Section G.4.1 of NEI 12-06 indicates the assessment should be performed by the licensee to address the impacts of the MSFHI on: (1) the sequence of events; (2) the design and implementation of the FLEX strategies; (3) the FLEX equipment storage; (4) the robustness of plant equipment; (5) the location of FLEX connection points; and (6) the flood protection features credited in the FLEX strategies.

Following its assessment, the licensee determined the following:

- The protection of FLEX equipment will not be affected by wind-wave runup since the flood levels at the storage locations, NW and SE locations, are well below the FLEX equipment. Specifically, the wind-wave runup elevations at the NW and SE locations are at a maximum of 25.4 feet MSL [mean sea level] while the FLEX equipment storage locations, is at elevation 27.5 feet MSL. Furthermore, the installed plant equipment supporting FLEX are within the reactor building and are not affected.

- Wind generated waves will not affect the deployment of the FLEX equipment since the waves are at a maximum intermittent runup depth of 1.9 feet along the NW and SE haul path. In addition, alternate paths for both NW and SE FLEX storage locations are less flooded and available to transport equipment to the deployment location at the turbine building NW wall.

- The FLEX equipment was evaluated for the worst-case flood height with wave runup and will still be capable of performing their functions due to the elevated heights of the transport trailers.

- The availability and access to all connection points is not impacted by the PMSS wind generated waves since they do not reach the ingress elevation of 23.5 feet MSL for Doors 9 and 14 of the reactor building.

- Procedural changes are not required for the PMSS.

On May 4, 2017, the NRC staff held an audit call with the licensee (ADAMS Accession No. ML17136A385). During this call, the NRC staff requested the licensee explain how FLEX actions are not impacted by PMSS flood debris, specifically in the area of by the intake structure (i.e., FLEX pump deployed location). The licensee explained that the FLEX pump hose staging area is at approximately elevation 13 ft. MSL, and can be procedurally moved to higher elevation (23 ft. MSL) prior to the PMSS levels reaching grade. In addition, the FLEX pump is shielded from large debris loads by structures to the east and smaller debris from the west will be restricted. With regard to the deployment paths, the licensee explained that the haul paths are shielded from large debris by structures to the east and small debris will be restricted from impacting the haul paths. Furthermore, the licensee stated that debris removal can be accomplished with the available FLEX deployment vehicles and the debris removal time has been accounted for in its validation plan.

During the audit, the NRC staff also requested the licensee explain how the deployment of FLEX equipment during the PMSS is not impacted considering postulated 1.9 feet wind-wave runup conditions. Specifically address ability of the FLEX truck to deploy FLEX equipment through 1.9 feet of wind-wave runup. The licensee explained that alternate paths for both NW and SE FLEX storage locations are available; both of which have more margin to transport equipment to the deployment location at the turbine building NW wall. Furthermore, the licensee clarified that the initiating event that would cause the PMSS provides the site with warning time that permits pre-deployment of the FLEX equipment. Even if pre-deployment was not completed, the licensee explained that its validation plan accounted for the period of inundation (~18 minutes), which provides flexibility for operators to delay deployment until floodwaters recede.

Based on the flood depths and the associated effects (i.e., debris loading and run-up) from the PMSS event compared to storage locations, available deployment paths and deployed location of FLEX equipment, the NRC staff finds it reasonable that the FLEX equipment is protected from the PMSS event and can be deployed/staged to implement the licensee's FLEX strategy. In addition, the NRC staff finds it reasonable that hoses and cables deployment paths are not impacted by the PMSS event due to the location of the entry points in the reactor building compared to the flood levels in these areas.

3.1.2 Local Intense Precipitation

The licensee performed an assessment consistent with Section G.4.1 of NEI 12-06 for the LIP flood hazard. Section G.4.1 of NEI 12-06 indicates the assessment should be performed by the licensee to address the impacts of the MSFHI on: (1) the sequence of events; (2) the design and implementation of the FLEX strategies; (3) the FLEX equipment storage; (4) the robustness of plant equipment; (5) the location of FLEX connection points; and (6) the flood protection features credited in the FLEX strategies.

Following its assessment, the licensee determined the following:

- The protection of FLEX equipment is not impacted by the LIP flood elevations at the NW and SE FLEX storage locations. Specifically the maximum LIP flood elevations at the NW and SE FLEX storage locations are 23.30 and 24.38 feet MSL, respectively, while the FLEX equipment storage locations, is at elevation 27.5 feet MSL. Installed plant equipment supporting FLEX are unaffected by this event since they are protected by the placement of sandbags at Doors 9 and 14. Warning time associated with a LIP event and placement of sandbags are procedurally controlled by station procedure OP-OC-108-109-1001, "Severe Weather Preparation."

- Sandbags are designed and implemented using guidance from the U.S. Army Corps of Engineers, which meet the performance criteria in Section G.5 of NEI 12-06, Revision 2.

- The LIP flood will not affect the deployment of the FLEX equipment since maximum flood depth is 0.88 feet along the haul path (from both NW and SE FLEX equipment storage locations) and at the deployment location. The tow vehicle and FLEX trailer mounted equipment have sufficient clearance to traverse the haul path when flooded.

- The availability and access to all connection points are maintained during the LIP flood using sandbag protection measures at reactor building Doors 9 and 14, which is procedurally controlled by station procedure OP-OC-108-109-1001, "Severe Weather Preparation."

- Procedural changes were made to address LIP warning time for proper staging of sandbags and for establishing the required height of the sandbags.

Based on the licensee's sequence of events in its FIP dated December 6, 2016, following the declaration of an ELAP event, the licensee has 90 minutes to deploy and stage the FLEX Pump and associated hoses with suction from the intake/discharge canal and the discharge hose routed to the turbine building NW door. Furthermore, approximately 2.5 hrs after the declaration of an ELAP event temporary electrical cables are deployed to the northwest turbine building access door. The licensee's flood hazard reevaluation report (FHRR) indicates that a LIP event is characterized, in part, as a 1-hr probable maximum precipitation event. Based on the duration of the LIP event and the expected deployment time for hoses and cables, the NRC staff finds it reasonable that floodwaters will have receded to low levels as not to impact the licensee's ability to implement its FLEX strategy.

Based on the flood depths from the LIP event compared to storage locations, available deployment paths and deployed location of FLEX equipment, the NRC staff finds it reasonable that the FLEX equipment is protected from the LIP event and can be deployed/staged to implement the licensee's FLEX strategy. In addition, the NRC staff finds it reasonable that hoses and cables deployment paths are not impacted by the LIP event due to the location of the entry points in the reactor building and the timing in which equipment will be routed through the northwest turbine building access door.

3.2. Evaluation of Associated Effects

The NRC staff reviewed information provided by the licensee regarding associated effects parameters for the Oyster Creek flood hazards not bounded by the CDB. Associated effects parameters related to water surface elevation (i.e., stillwater elevation with wind waves and runup effects) were previously reviewed by the NRC staff, and were transmitted to the licensee via the ISR letter dated February 9, 2016. The associated effects parameters not directly associated with water surface elevation are discussed below and are summarized in Table 3.2 of this document.

3.2.1 Local Intense Precipitation

For the LIP flood-causing mechanism, the licensee stated that the associated effects of LIP flooding are not considered credible (i.e., they are minimal) due to the relative-low flow velocities and limited debris effects within the protected area. The NRC staff confirmed this statement by reviewing the licensee-provided LIP model input and output files. The NRC staff found that the estimated inundation depths and flow velocities are reasonable and acceptable for use in the Oyster Creek MSA. The NRC staff agrees with the licensee's conclusion that the associated effects parameters values for LIP are minimal.

3.2.2 Probable Maximum Storm Surge

For storm surge flood-causing mechanism, the licensee reported hydrodynamic loads ranging from 0.7 lb/ft^2 to 10.5 lb/ft^2, and a maximum wave load of 756.8 lb/ft^2. These water-borne loads were estimated based on the storm surge depths using a numerical storm surge model. The NRC staff independently reviewed the model-generated storm surge output provided by the licensee. Based on the review of the storm surge numerical model results, the NRC staff concludes that the licensee's hydrodynamic and wave loads are acceptable and reasonable for use as part of the Oyster Creek MSA review.

The Oyster Creek FHRR discusses potential debris impact loading from floating woody debris of 2,000 lbs weight, ice debris of 4,000 lbs, and a water-borne boat of 8,125 lbs. The debris velocity used was the summation of the maximum flow velocity and wave velocity ranging from 2.3 ft/sec to 8.8 ft/sec at different locations within the powerblock and at the intake structure location. The maximum debris load of 64,950 lbs was obtained, which is impact load from boat debris at the site emergency building location. The NRC staff reviewed the calculation of the debris loads and the maximum velocities applied to the calculation in the Oyster Creek FHRR. The NRC staff confirmed that the postulated debris sources and load computation follow the guideline of ASCE 7-10. The NRC staff found that the calculation is accurate and the assumptions are conservative. Therefore, the NRC staff concluded that the licensee's estimation of the debris loads are acceptable for use in the Oyster Creek MSA.

The licensee stated in the Oyster Creek MSA that other associated effects parameters for the storm surge events are either minimal or not applicable at the site. The NRC staff agrees with the licensee's conclusion for the storm surge associated effects parameters and also notes the approach is consistent with guidance provided by Appendix G of NEI 12-06, Revision 2. The NRC staff also agrees with the licensee's determination that associated effects have no impact on FLEX strategies. In summary, the NRC staff determined the licensee's methods were appropriate and the provided associated effects parameters are reasonable for use in the Oyster Creek MSA.

3.3 Evaluation of Flood Event Duration

The NRC staff reviewed information provided by the licensee regarding flood event duration (FED) parameters for the Oyster Creek flood hazards not bounded by the CDB. The FED parameters for the flood-causing mechanisms not bounded by the CDB are summarized in Table 3.3 of this document.

3.3.1 Local Intense Precipitation

The licensee stated in the Oyster Creek MSA that LIP warning time procedures were developed, per the NEI 15-05 guidance, to provide sufficient time to deploy and install the sandbags. The NRC staff endorsed NEI 15-05 to determine LIP warning time for use in the MSA submittals.

The maximum water surface elevation generated during the LIP event described in the Oyster Creek FHRR exceeds the elevation of only one door threshold within the Oyster Creek powerblock; which is the door at the turbine building location. The licensee reported the duration of inundation is 1.5 hrs. The time necessary for LIP-related flood waters to recede from the Oyster Creek site is about 6.5 hrs.

The licensee used results from 2-dimentional numerical modeling, as described in the Oyster Creek FHRR, to determine the inundation and recession periods. The NRC staff confirmed that the licensee's reevaluation of the inundation and recession periods for the LIP events used present-day methodologies and regulatory guidance. Based on this review, the NRC staff determined that the licensee's FED parameters for LIP are reasonable and acceptable for use in the Oyster Creek MSA.

3.3.2 Probable Maximum Storm Surge

In the Oyster Creek FHRR, the licensee notes that conventional weather forecasting organizations can be utilized to estimate when an impending hurricane might make landfall at or near the Oyster Creek site. The National Oceanic and Atmospheric Administration (NOAA) hurricane forecasts, for example, are one such source that has reliably predicted hurricanes more than 48 hrs in advance of making landfall.

The licensee reported that the warning time is 22.3 hrs starting from the onset of the probable maximum hurricane and that the duration of flooding due to storm surge is transient event limited to approximately 0.3 hrs in duration; however, no recession time was reported as the licensee observed that the inundation water depth was shallow given the nature of transient surge-related flooding expected at the site (thus, a minimal recession period). The licensee relied on the ADvanced CIRCulation (ADCIRC) computer code developed to estimate the various flooding parameters due to storm surge at the Oyster Creek site. In connection with the development of the Oyster Creek ISR letter, the NRC staff independently reviewed the model-generated storm surge hydrograph provided by the licensee. Based on a review of the storm surge numerical model results, the NRC staff concludes that the licensee's FED parameters are acceptable and reasonable for use as part of the Oyster Creek MSA review and have no impact on FLEX strategies.

4.0 CONCLUSION

The NRC staff has reviewed the information provided in the Oyster Creek MSA related to the original FLEX strategies, as evaluated against the reevaluated hazards described in Section 2 of this staff assessment, and found that:

- The FLEX strategies are not affected by the impacts of the ISR flood levels (including impacts due to the environmental conditions created by the ISR flood levels);

- The deployment of the FLEX strategies, as described in the FIP (which is under review by the NRC staff) and subject to subsequent inspection, is not affected by the impacts of the ISR flood levels; and

- Associated effects and FED are reasonable and acceptable for use in the MSA, and have been appropriately considered in the MSA.

Therefore, the NRC staff concludes that the licensee has followed the guidance in Appendix G of NEI 12-06, Revision 2, and demonstrated the capability to deploy the original FLEX strategies, as designed, against a postulated beyond-design-basis event for the LIP and probable maximum storm surge flood-causing mechanisms, including associated effects and FED.

Table 3.2. Oyster Creek's Associated Effects Parameters not Directly Associated with Total Water Height for Flood Causing Mechanisms not Bounded by the CDB

Associated Effects Parameter	LOCAL INTENSE PRECIPITATION	STORM SURGE	
Hydrodynamic loading at plant grade	6.67 lb/ft (1)	10.5 lb/ft^2 (2) *Intake Structure*	24.4 lb/ft^2 *Power Block*
Debris loading at plant grade	Minimal	< 64,950 lbs (3)	
Sediment loading at plant grade	Minimal	Minimal	
Sediment deposition and erosion	Minimal	Minimal	
Concurrent conditions, including adverse weather	Minimal	Not Applicable	
Groundwater ingress	Minimal	Not Applicable	
Other pertinent factors (e.g., waterborne projectiles)	Minimal	Not Applicable	

Source: Oyster Creek MSA

Notes:

(1) lb/ft refers to pounds per linear foot of structure in length.

(2) lb/ft^2 refers to pounds per square foot.

(3) Due to boat impact load

Table 3.3. Oyster Creek's Flood Event Durations for Flood-Causing Mechanisms Not Bounded by the CDB

FLOOD-CAUSING MECHANISM	TIME AVAILABLE FOR PREPARATION FOR FLOOD EVENT	DURATION OF INUNDATION OF SITE	TIME FOR WATER TO RECEDE FROM SITE
Local Intense Precipitation and Associated Drainage	Guidance provided in NEI 15-05	1.5 hrs [(1)]	6.5 hrs [(1)]
Storm Surge (Combined Event)	23 hrs	0.3 hrs	minimal

(1) As provided in Oyster Creek MSA
(2) Estimate based on NRC staff's review of the licensee's ADCIRC computer model.

OYSTER CREEK NUCLEAR GENERATING STATION– FLOOD HAZARD MITIGATION STRATEGIES ASSESSMENT DATED May 18, 2017

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