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

June 30, 2017

Mr. Peter P. Sena, III
President and Chief Nuclear Officer
PSEG Nuclear LLC – N09
P.O. Box 236
Hancocks Bridge, NJ 08038

SUBJECT: HOPE CREEK GENERATING STATION – SAFETY EVALUATION REGARDING IMPLEMENTATION OF MITIGATING STRATEGIES AND RELIABLE SPENT FUEL POOL INSTRUMENTATION RELATED TO ORDERS EA-12-049 AND EA-12-051 (CAC NOS. MF0867 AND MF1031)

Dear Mr. Sena:

On March 12, 2012, the U.S. Nuclear Regulatory Commission (NRC) issued Order EA-12-049, "Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond Design-Basis External Events" and Order EA-12-051, "Order to Modify Licenses With Regard To Reliable Spent Fuel Pool Instrumentation," (Agencywide Documents Access and Management System (ADAMS) Accession Nos. ML12054A736 and ML12054A679, respectively). The orders require holders of operating reactor licenses and construction permits issued under Title 10 of the *Code of Federal Regulations* Part 50 to modify the plants to provide additional capabilities and defense-in-depth for responding to beyond-design-basis external events, and to submit for review Overall Integrated Plans (OIPs) that describe how compliance with the requirements of Attachment 2 of each order will be achieved.

By letter dated February 27, 2013 (ADAMS Accession No. ML13059A272), PSEG Nuclear LLC (PSEG, the licensee) submitted its OIP for Hope Creek Generating Station (Hope Creek) in response to Order EA-12-049. At six-month intervals following the submittal of the OIP, the licensee submitted reports on its progress in complying with Order EA-12-049. These reports were required by the order, and are listed in the attached safety evaluation (SE). By letter dated August 28, 2013 (ADAMS Accession No. ML13234A503), the NRC notified all licensees and construction permit holders that the staff is conducting audits of their responses to Order EA-12-049 in accordance with NRC Office of Nuclear Reactor Regulation (NRR) Office Instruction LIC-111, "Regulatory Audits," (ADAMS Accession No. ML082900195). By letters dated February 11, 2014 (ADAMS Accession No. ML13365A253), and March 25, 2016 (ADAMS Accession No. ML16053A151), the NRC issued an Interim Staff Evaluation (ISE) and audit report, respectively, on the licensee's progress. By letter dated January 25, 2017 (ADAMS Accession No. ML17025A005), PSEG submitted a compliance letter and Final Integrated Plan (FIP) in response to Order EA-12-049. The compliance letter stated that the licensee had achieved full compliance with Order EA-12-049.

By letter dated February 27, 2013 (ADAMS Accession No. ML130720035), PSEG submitted its OIP for Hope Creek in response to Order EA-12-051. At six-month intervals following the submittal of the OIP, the licensee submitted reports on its progress in complying with Order EA-12-051. These reports were required by the order, and are listed in the attached SE. By letters dated November 22, 2013 (ADAMS Accession No. ML13309B592), and March 25, 2016 (ADAMS Accession No. ML16053A151), the NRC staff issued an ISE and audit report, respectively, on the licensee's progress. By letter dated March 26, 2014 (ADAMS Accession No. ML14083A620), the NRC notified all licensees and construction permit holders that the staff is conducting audits of their responses to Order EA-12-051 in accordance with NRC NRR Office Instruction LIC-111, similar to the process used for Order EA-12-049. By letter dated July 28, 2015 (ADAMS Accession No. ML15209A867), PSEG submitted a compliance letter in response to Order EA-12-051. The compliance letter stated that the licensee had achieved full compliance with Order EA-12-051.

The enclosed SE provides the results of the NRC staff's review of PSEG's strategies for Hope Creek. The intent of the SE is to inform PSEG on whether or not its integrated plans, if implemented as described, appear to adequately address the requirements of Orders EA-12-049 and EA-12-051. The staff will evaluate implementation of the plans through inspection, using Temporary Instruction 2515-191, "Implementation of Mitigation Strategies and Spent Fuel Pool Instrumentation Orders and Emergency Preparedness Communications/Staffing/ Multi-Unit Dose Assessment Plans" (ADAMS Accession No. ML15257A188). This inspection will be conducted in accordance with the NRC's inspection schedule for the plant.

If you have any questions, please contact John Boska, Orders Management Branch, Hope Creek Project Manager, at 301-415-2901 or at John.Boska@nrc.gov.

Sincerely,

Tony Brown, Acting Chief
Orders Management Branch
Japan Lessons-Learned Division
Office of Nuclear Reactor Regulation

Docket No.: 50-354

Enclosure:
Safety Evaluation

cc w/encl: Distribution via Listserv

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UNITED STATES
NUCLEAR REGULATORY COMMISSION
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SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATED TO ORDERS EA-12-049 AND EA-12-051

PSEG NUCLEAR LLC

HOPE CREEK GENERATING STATION

DOCKET NO. 50-354

1.0 INTRODUCTION

The earthquake and tsunami at the Fukushima Dai-ichi nuclear power plant in March 2011 highlighted the possibility that extreme natural phenomena could challenge the prevention, mitigation, and emergency preparedness defense-in-depth layers already in place in nuclear power plants in the United States. At Fukushima, limitations in time and unpredictable conditions associated with the accident significantly challenged attempts by the responders to preclude core damage and containment failure. During the events in Fukushima, the challenges faced by the operators were beyond any faced previously at a commercial nuclear reactor and beyond the anticipated design-basis of the plants. The U.S. Nuclear Regulatory Commission (NRC) determined that additional requirements needed to be imposed at U.S. commercial power reactors to mitigate such beyond-design-basis external events (BDBEEs).

On March 12, 2012, the NRC issued Order EA-12-049, "Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events" [Reference 4]. This order directed licensees to develop, implement, and maintain guidance and strategies to maintain or restore core cooling, containment, and spent fuel pool (SFP) cooling capabilities in the event of a BDBEE. Order EA-12-049 applies to all power reactor licensees and all holders of construction permits for power reactors.

On March 12, 2012, the NRC also issued Order EA-12-051, "Order Modifying Licenses With Regard to Reliable Spent Fuel Pool Instrumentation" [Reference 5]. This order directed licensees to install reliable SFP level instrumentation with a primary channel and a backup channel, and with independent power supplies that are independent of the plant alternating current (ac) and direct current (dc) power distribution systems. Order EA-12-051 applies to all power reactor licensees and all holders of construction permits for power reactors.

2.0 REGULATORY EVALUATION

Following the events at the Fukushima Dai-ichi nuclear power plant on March 11, 2011, the NRC established a senior-level agency task force referred to as the Near-Term Task Force (NTTF). The NTTF was tasked with conducting a systematic and methodical review of the NRC regulations and processes and determining if the agency should make additional improvements

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to these programs in light of the events at Fukushima Dai-ichi. As a result of this review, the NTTF developed a comprehensive set of recommendations, documented in SECY-11-0093, "Near-Term Report and Recommendations for Agency Actions Following the Events in Japan," dated July 12, 2011 [Reference 1]. Following interactions with stakeholders, these recommendations were enhanced by the NRC staff and presented to the Commission.

On February 17, 2012, the NRC staff provided SECY-12-0025, "Proposed Orders and Requests for Information in Response to Lessons Learned from Japan's March 11, 2011, Great Tohoku Earthquake and Tsunami," [Reference 2] to the Commission. This paper included a proposal to order licensees to implement enhanced BDBEE mitigation strategies. As directed by the Commission in staff requirements memorandum (SRM)-SECY-12-0025 [Reference 3], the NRC staff issued Orders EA-12-049 and EA-12-051.

2.1 Order EA-12-049

Order EA-12-049, Attachment 2, [Reference 4] requires that operating power reactor licensees and construction permit holders use a three-phase approach for mitigating BDBEEs. The initial phase requires the use of installed equipment and resources to maintain or restore core cooling, containment and SFP cooling capabilities. The transition phase requires providing sufficient, portable, onsite equipment and consumables to maintain or restore these functions until they can be accomplished with resources brought from off site. The final phase requires obtaining sufficient offsite resources to sustain those functions indefinitely. Specific requirements of the order are listed below:

1) Licensees or construction permit (CP) holders shall develop, implement, and maintain guidance and strategies to maintain or restore core cooling, containment, and SFP cooling capabilities following a beyond-design-basis external event.

2) These strategies must be capable of mitigating a simultaneous loss of all alternating current (ac) power and loss of normal access to the ultimate heat sink [UHS] and have adequate capacity to address challenges to core cooling, containment, and SFP cooling capabilities at all units on a site subject to this Order.

3) Licensees or CP holders must provide reasonable protection for the associated equipment from external events. Such protection must demonstrate that there is adequate capacity to address challenges to core cooling, containment, and SFP cooling capabilities at all units on a site subject to this Order.

4) Licensees or CP holders must be capable of implementing the strategies in all modes of operation.

5) Full compliance shall include procedures, guidance, training, and acquisition, staging, or installing of equipment needed for the strategies.

On August 21, 2012, following several submittals and discussions in public meetings with NRC staff, the Nuclear Energy Institute (NEI) submitted document NEI 12-06, "Diverse and Flexible

Coping Strategies (FLEX) Implementation Guide," Revision 0 [Reference 6] to the NRC to provide specifications for an industry-developed methodology for the development, implementation, and maintenance of guidance and strategies in response to the Mitigation Strategies order. The NRC staff reviewed NEI 12-06 and on August 29, 2012, issued its final version of Japan Lessons-Learned Directorate (JLD) Interim Staff Guidance (ISG) JLD-ISG-2012-01, "Compliance with Order EA-12-049, Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events" [Reference 7], endorsing NEI 12-06, Revision 0, with comments, as an acceptable means of meeting the requirements of Order EA-12-049, and published a notice of its availability in the *Federal Register* (77 FR 55230).

2.2 Order EA-12-051

Order EA-12-051, Attachment 2, [Reference 5] requires that operating power reactor licensees and construction permit holders install reliable SFP level instrumentation. Specific requirements of the order are listed below:

> All licensees identified in Attachment 1 to the order shall have a reliable indication of the water level in associated spent fuel storage pools capable of supporting identification of the following pool water level conditions by trained personnel: (1) level that is adequate to support operation of the normal fuel pool cooling system, (2) level that is adequate to provide substantial radiation shielding for a person standing on the spent fuel pool operating deck, and (3) level where fuel remains covered and actions to implement make-up water addition should no longer be deferred.
>
> 1. The spent fuel pool level instrumentation shall include the following design features:
>
> 1.1 Instruments: The instrumentation shall consist of a permanent, fixed primary instrument channel and a backup instrument channel. The backup instrument channel may be fixed or portable. Portable instruments shall have capabilities that enhance the ability of trained personnel to monitor spent fuel pool water level under conditions that restrict direct personnel access to the pool, such as partial structural damage, high radiation levels, or heat and humidity from a boiling pool.
>
> 1.2 Arrangement: The spent fuel pool level instrument channels shall be arranged in a manner that provides reasonable protection of the level indication function against missiles that may result from damage to the structure over the spent fuel pool. This protection may be provided by locating the primary instrument channel and fixed portions of the backup instrument channel, if applicable, to maintain instrument channel separation within the spent fuel pool area, and to utilize inherent shielding from missiles provided by existing recesses and corners in the spent fuel pool structure.

1.3 Mounting: Installed instrument channel equipment within the spent fuel pool shall be mounted to retain its design configuration during and following the maximum seismic ground motion considered in the design of the spent fuel pool structure.

1.4 Qualification: The primary and backup instrument channels shall be reliable at temperature, humidity, and radiation levels consistent with the spent fuel pool water at saturation conditions for an extended period. This reliability shall be established through use of an augmented quality assurance process (e.g., a process similar to that applied to the site fire protection program).

1.5 Independence: The primary instrument channel shall be independent of the backup instrument channel.

1.6 Power supplies: Permanently installed instrumentation channels shall each be powered by a separate power supply. Permanently installed and portable instrumentation channels shall provide for power connections from sources independent of the plant ac and dc power distribution systems, such as portable generators or replaceable batteries. Onsite generators used as an alternate power source and replaceable batteries used for instrument channel power shall have sufficient capacity to maintain the level indication function until offsite resource availability is reasonably assured.

1.7 Accuracy: The instrument channels shall maintain their designed accuracy following a power interruption or change in power source without recalibration.

1.8 Testing: The instrument channel design shall provide for routine testing and calibration.

1.9 Display: Trained personnel shall be able to monitor the spent fuel pool water level from the control room, alternate shutdown panel, or other appropriate and accessible location. The display shall provide on-demand or continuous indication of spent fuel pool water level.

2. The spent fuel pool instrumentation shall be maintained available and reliable through appropriate development and implementation of the following programs:

2.1 Training: Personnel shall be trained in the use and the provision of alternate power to the primary and backup instrument channels.

2.2 Procedures: Procedures shall be established and maintained for the testing, calibration, and use of the primary and backup spent fuel pool instrument channels.

2.3 Testing and Calibration: Processes shall be established and maintained for scheduling and implementing necessary testing and calibration of the primary and backup spent fuel pool level instrument channels to maintain the instrument channels at the design accuracy.

On August 24, 2012, following several NEI submittals and discussions in public meetings with NRC staff, the NEI submitted document NEI 12-02, "Industry Guidance for Compliance With NRC Order EA-12-051, To Modify Licenses With Regard to Reliable Spent Fuel Pool Instrumentation," Revision 1 [Reference 8] to the NRC to provide specifications for an industry-developed methodology for compliance with Order EA-12-051. On August 29, 2012, the NRC staff issued its final version of JLD-ISG-2012-03, "Compliance with Order EA-12-051, Reliable Spent Fuel Pool Instrumentation" [Reference 9], endorsing NEI 12-02, Revision 1, as an acceptable means of meeting the requirements of Order EA-12-051 with certain clarifications and exceptions, and published a notice of its availability in the *Federal Register* (77 FR 55232).

3.0 TECHNICAL EVALUATION OF ORDER EA-12-049

By letter dated February 27, 2013 [Reference 10], PSEG Nuclear LLC (PSEG, the licensee) submitted an Overall Integrated Plan (OIP) for Hope Creek Generating Station (Hope Creek, HCGS) in response to Order EA-12-049. By letters dated August 22, 2013 [Reference 11], February 25, 2014 [Reference 12], August 26, 2014 [Reference 13], February 18, 2015 [Reference 14], August 27, 2015 [Reference 48], February 29, 2016 [Reference 49], and August 24, 2016 [Reference 50], the licensee submitted six-month updates to the OIP. By letter dated August 28, 2013 [Reference 15], the NRC notified all licensees and construction permit holders that the staff is conducting audits of their responses to Order EA-12-049 in accordance with NRC Office of Nuclear Reactor Regulation (NRR) Office Instruction LIC-111, "Regulatory Audits" [Reference 36]. By letters dated February 11, 2014 [Reference 16], and March 25, 2016 [Reference 17], the NRC issued an Interim Staff Evaluation (ISE) and audit report, respectively, on the licensee's progress. By letter dated January 25, 2017 [Reference 18], the licensee reported that full compliance with the requirements of Order EA-12-049 was achieved, and submitted a Final Integrated Plan (FIP).

3.1 Overall Mitigation Strategy

Attachment 2 to Order EA-12-049 describes the three-phase approach required for mitigating BDBEEs in order to maintain or restore core cooling, containment, and SFP cooling capabilities. The phases consist of an initial phase (Phase 1) using installed equipment and resources, followed by a transition phase (Phase 2) in which portable onsite equipment is placed in service, and a final phase (Phase 3) in which offsite resources may be placed in service. The timing of when to transition to the next phase is determined by plant-specific analyses.

While the initiating event is undefined, it is assumed to result in an extended loss of ac power (ELAP) with a loss of normal access to the UHS. Thus, the ELAP with loss of normal access to the UHS is used as a surrogate for a BDBEE. The initial conditions and assumptions for the analyses are stated in NEI 12-06, Section 3.2.1, and include the following:

1. The reactor is assumed to have safely shut down with all rods inserted (subcritical).
2. The dc power supplied by the plant batteries is initially available, as is the ac power from inverters supplied by those batteries; however, over time the batteries may be depleted.
3. There is no core damage initially.
4. There is no assumption of any concurrent event.
5. Because the loss of ac power presupposes random failures of safety-related equipment (emergency power sources), there is no requirement to consider further random failures.

Hope Creek is a General Electric boiling-water reactor (BWR) Model 4 with a Mark I containment. The licensee's three-phase approach to mitigate a postulated ELAP event, as described in the FIP, is summarized below. The approach is somewhat different if the plant receives warning of a pending flood, as discussed in Section 3.2.2. below. There is only one operating reactor at Hope Creek, as construction was started on Unit 2 but never completed. The licensee is using some Unit 2 buildings for parts of the FLEX strategy.

At the onset of an ELAP, the reactor is assumed to scram from full power. Main steam isolation valves (MSIVs) automatically close and feedwater is lost. Core decay heat is removed when the safety relief valves (SRVs) open on operator action or high pressure and release steam from the reactor pressure vessel (RPV) to the suppression pool (torus), which is part of the primary containment structure. Makeup to the RPV is provided by the reactor core isolation cooling (RCIC) turbine-driven pump and the high-pressure coolant injection (HPCI) turbine-driven pump. Both pump suctions are normally aligned to the condensate storage tank (CST). Because the CST is not protected from tornado missiles or flooding, the licensee's mitigating strategy assumes that the RCIC and HPCI pump suctions realign to the suppression pool. If the CST is available, the operators will initially realign the pump suctions to the suppression pool to save the cooler CST water, and when the suppression pool heats up, they will realign the RCIC and HPCI pump suctions back to the CST.

An ELAP will be declared within about an hour of event initiation if it has been determined that the emergency diesel generators (EDGs) cannot be restored to service within 4 hours and offsite power will remain unavailable. The HPCI injection will be terminated as soon as RCIC is capable of controlling RPV level alone, which is normally approximately 20 minutes after the scram. When the suppression pool heats up to about 200 degrees Fahrenheit (°F), operators open the torus vent to atmosphere to mitigate the temperature rise and allow the RCIC system to continue to function. The RPV makeup will continue to be provided from the RCIC system for as long as possible, since it is a closed loop system using relatively clean suppression pool water.

When the RCIC system is no longer available, the RPV makeup supply in Phase 2 can come from either of two sources. Operators use the SRVs to depressurize the RPV to below the discharge pressure of the selected water supply. One source is from a FLEX alternate header pump, which is driven by an electric motor. Two of these pumps (one is a spare) are pre-staged in the B core spray pump room in the Unit 1 reactor building. The pump suction can be aligned to either the CST or the suppression pool, which are relatively clean water sources, and the discharge can be aligned to residual heat removal (RHR) system piping which provides a flow path into the RPV. The electric power to drive the pump comes from a FLEX diesel generator (DG), which energizes the 480 volt ac (Vac) FLEX motor control center (MCC) located in the Unit 2 auxiliary building. The FLEX alternate header pump is powered from the FLEX MCC.

Another source of water for RPV makeup comes from the diesel-driven FLEX service water pump, which will be deployed at the Delaware River near the service water intake structure (SWIS) to pump river water through the service water system piping to the reactor building, where the RHR emergency makeup line from the service water piping is used to direct water into the RHR system and from there into the RPV.

Hope Creek has a Mark I containment, which is inerted with nitrogen at power. The licensee performed a containment evaluation and determined that opening the torus vent to atmosphere will allow containment temperature and pressure to stay within acceptable levels until equipment from a National Strategic Alliance of FLEX Emergency Response (SAFER) Response Center (NSRC) can be set up for cooling of the suppression pool, which is in the torus.

Hope Creek has an SFP located in the reactor building. To maintain SFP cooling capabilities, the licensee stated that the required action is to establish the water injection lineup before the environment on the SFP refueling floor degrades due to boiling in the pool so that personnel can access the refueling floor to accomplish the coping strategies. The pool will initially heat up due to the unavailability of the normal cooling system. In Technical Evaluation 70127346-0230, the licensee determined that the minimum time to boil after loss of cooling during power operations is about 37 hours. Since the refueling floor will become an adverse environment soon after boiling starts, all preparations to secure a FLEX hose or pipe to the SFP will be complete before boiling starts. The licensee stated that the operators will be capable of completing the hose connections to the SFP within 13 hours of the event, and adding water to the SFP within 18.4 hours of the event. The minimum time to boil during shutdown with a full core offload is discussed in Section 3.11 below.

In its FIP, the licensee described that two FLEX pumps are able to provide water to the SFP. One strategy is to connect FLEX hoses to provide a flow path for the diesel-driven FLEX service water pump to supply river water to the SFP. The alternate strategy is to align a flow path to the SFP from the FLEX alternate header pump, which is pre-staged in the B core spray pump room.

The licensee stated in its FIP that the operators will perform dc bus load stripping within the initial 1.5 hours following event initiation to ensure safety-related battery life is extended to at least 5 hours. Following dc load stripping and prior to battery depletion, one 600 kilowatt (kW), 480 Vac FLEX DG will be started and connected to the FLEX MCC in order to power FLEX electrical loads. This FLEX DG will be used to repower essential battery chargers within 5 hours of ELAP initiation, as well as powering the FLEX alternate header pump.

In addition, an NSRC will provide high capacity pumps and large combustion turbine generators (CTGs) which could be used to restore an RHR cooling train to cool the core in the long-term. There are two NSRCs in the United States.

Below are specific details on the licensee's strategies to restore or maintain core cooling, containment, and SFP cooling capabilities in the event of a BDBEE, and the results of the staff's review of these strategies. The NRC staff evaluated the licensee's strategies against the endorsed NEI 12-06, Revision 0, guidance.

3.2 Reactor Core Cooling Strategies

Order EA-12-049 requires licensees to maintain or restore cooling to the reactor core in the event of an ELAP concurrent with a loss of normal access to the UHS. Although the ELAP results in an immediate trip of the reactor, sufficient core cooling must be provided to account for fission product decay and other sources of residual heat. Consistent with endorsed guidance from NEI 12-06, Phase 1 of the licensee's core cooling strategy credits installed equipment (other than that presumed lost to the ELAP with loss of normal access to the UHS) that is robust in accordance with the guidance in NEI 12-06. In Phase 2, robust installed equipment is supplemented by onsite FLEX equipment, which is used to cool the core either directly (e.g., pumps and hoses) or indirectly (e.g., FLEX electrical generators and cables repowering robust installed equipment). The equipment available onsite for Phases 1 and 2 is further supplemented in Phase 3 by equipment transported from the NSRCs.

As reviewed in this section, the licensee's core cooling analysis for the ELAP with loss of normal access to the UHS event presumes that, per endorsed guidance from NEI 12-06, the unit would have been operating at full power prior to the event. Therefore, the suppression pool may be credited as the heat sink for core cooling during the ELAP. Maintenance of sufficient RPV inventory, despite steam release from the SRVs and ongoing system leakage expected under ELAP conditions, is accomplished through a combination of installed systems and FLEX equipment. The specific means used by the licensee to accomplish adequate core cooling during the ELAP event are discussed in further detail below. The licensee's strategy for ensuring compliance with Order EA-12-049 for conditions where the unit is shut down, or being refueled, is reviewed separately in Section 3.11 of this evaluation.

3.2.1 Core Cooling Strategy and RPV Makeup

3.2.1.1 Phase 1

Per the Hope Creek FIP, the initial injection of cooling water into the RPV will be accomplished using the RCIC and HPCI systems. Both the RCIC and HPCI pump suctions are initially lined up to the CST and they will pump water into the RPV from the CST automatically. The CST is not robust for all applicable hazards, and thus cannot be credited to be available in all FLEX scenarios; if the CST is not available, RCIC and HPCI pump suctions will automatically transfer to the suppression pool, also known as the torus. The suppression pool is fully protected from all external hazards and is the credited source of water for this event. The suction swap-over function from the CST to the suppression pool is fully protected from external hazards.

Turbines using steam from the RPV power both the RCIC and HPCI pumps. Both systems are robust for the hazards considered in the ELAP evaluation. Both the RCIC and HPCI pumps are designed to automatically start when the RPV water level lowers to the "low-low" setpoint. In order to minimize suppression pool heatup, operators will secure the HPCI system when the RCIC system is capable of maintaining RPV water inventory. This will occur approximately 20 minutes after the initiation of the ELAP event. The RCIC discharges into a main feedwater line to the RPV feedwater spray nozzle. The RCIC system valves are powered by the dc electric system. The turbine speed control is used to control the cooling flow to the RPV, balancing it with the outflow of steam through the SRVs to the suppression pool in order to maintain the RPV level within its desired control band.

Pressure control of the RPV is accomplished using the SRVs, which are controlled using 125 Volt dc (Vdc) control power from the safety-related batteries, and compressed gas as the motive force. At approximately 1 hour after the initiation of the event, operators will initiate actions to release additional steam through the SRVs. This reduces RPV pressure at a rate which the operator controls to cool the RPV at less than 100 °F per hour. After this cooldown, the reactor pressure is maintained at approximately 200 pounds per square inch gage (psig) to allow continued operation of either the RCIC or HPCI system.

At approximately 4 hours after the start of the ELAP, SRV discharges and RCIC pump exhaust will have caused suppression pool water temperature to reach 200 °F based on thermal calculations. At approximately 4 hours after the initiation of the ELAP, in accordance with the procedural direction provided, the modified suppression pool vent is opened to remove containment heat. The licensee calculates that opening the containment vent at this time will limit the torus temperature rise to a peak of 250 °F. The vent system is supplied with electrical power from an uninterruptable power supply inverter. The licensee's FIP indicates that RCIC can continue to function with temperatures as high as 255 °F, however, the licensee plans on transferring core cooling to the FLEX equipment prior to reaching this point.

The SRVs are safety-related equipment that are located inside the containment drywell and protected from all external hazards. They are normally supplied with compressed air from the primary containment instrument gas (PCIG) system. Additionally, they have individual backup air accumulators, which have sufficient capacity to cycle each of the 14 SRVs 26 times. The SRVs are powered from the Class 1E 125 Vdc distribution system. The licensee stated that the SRVs are environmentally qualified for conditions reached in the drywell during the ELAP event.

Hope Creek's batteries and Class 1E 125 Vdc distribution system provide power to RCIC systems, SRVs and required instrumentation. The dc load shedding is initiated after approximately 30 minutes, as part of Station Blackout response, by shedding non-Class 1E loads. If an ELAP is declared then additional unnecessary loads are shed within 1.5 hours after the initiation of the ELAP event to extend the Class 1E battery capacity to power the Phase 1 systems and instruments. Installed batteries can maintain necessary voltage for at least 5 hours. Prior to battery depletion, FLEX diesel generators are deployed and used to recharge the 250 Vdc and 125 Vdc batteries.

3.2.1.2 Phase 2

Core cooling transitions from Phase 1 to Phase 2 at about 5 hours from the start of the ELAP. The timing of this transition is based on the licensee's battery sizing evaluations. Based on the licensee's evaluation and load shedding strategy, the station batteries are capable of providing power for the RCIC system and SRVs for at least 5 hours. Station operators will connect a 600 kw, 480 Vac FLEX generator to the FLEX MCC and reenergize 250 Vdc and 125 Vdc battery chargers within this 5 hour period. This should ensure uninterrupted power to critical components from the dc electrical system.

During Phase 2 operations HCGS intends to continue the use of the RCIC or HPCI system to provide water for core cooling. In order to maintain sufficient steam pressure for these systems to operate, RPV pressure will be maintained above 150 psig.

The FLEX generator will also supply a portable air compressor that will be connected to the PCIG system. This provides assurance that the SRVs will have 125 Vdc power available for their logic and an air supply for their motive force.

The FLEX Phase 2 strategy deploys a FLEX electric motor-driven alternate header pump, which is powered from the FLEX MCC, at about 5 hours after the start of the event. This FLEX pump will take suction on the CST or the torus as preferred water sources and inject water into the RPV via a primary or alternate connection. The primary connection is at the B service water (SW) to RHR emergency makeup flowpath. The alternate connection is at the A RHR heat exchanger. This pump is not affected by flooding at the site.

The FLEX Phase 2 strategy also deploys a portable diesel-driven FLEX pump to take suction from the Delaware River, which is an unlimited supply of lower quality water. The pump will be positioned near the service water intake structure and will take suction from the river via a suction hose equipped with a strainer. A discharge hose will connect the pump to connections on either the A or B service water header. Downstream heat exchanger loads such as the safety auxiliaries cooling system and reactor auxiliaries cooling system will be isolated so that the FLEX pump will pressurize the service water piping to the reactor building. Water will flow from the service water header to the RHR header via the service water to RHR emergency makeup line. River water will be injected to the RPV inside the shroud and above the fuel. Even if flood waters delay the deployment, the licensee's timeline in the FIP shows it will be available at about 18.4 hours. In conjunction with the licensee's plans to limit suppression pool heatup, this timing should provide adequate margin.

The portable diesel-driven FLEX pump will also be used to replenish torus water level as necessary by supplying water to the torus spray header or the RHR test return valve.

3.2.1.3 Phase 3

The Phase 3 strategy includes the use of equipment from an NSRC. The plant intends to utilize equipment provided by an NSRC in conjunction with installed plant equipment to restore shutdown cooling. Electrical power from four 4.16 kV generators and a distribution system will be used to restore one division of Emergency Core Cooling System (ECCS) equipment. The NSRC-provided low-pressure high-flow diesel-driven pump would be used to pump water from the UHS (Delaware River) and through the safety auxiliaries cooling system (SACS) heat exchanger to restore the heat sink function. A mobile water treatment system will be provided from the NSRC for water purification.

3.2.2 Variations to Core Cooling Strategy for Flooding Event

The flooding of concern is a result of hurricane storm surge at the site. The licensee receives advance warning of an approaching hurricane and takes actions to improve the safety profile at the site. HCGS has a nominal grade elevation of 101.5 feet Public Service Datum (PSD), which is equal to 12.5 feet above mean sea level (MSL). As described in Section 3.5.2 below, the current design-basis maximum flood level is a still water elevation of 113.8 feet PSD, which means the site would be flooded with 12.3 feet of water above grade level. The licensee stated in its FIP that the plant's minimum flood-protected elevation is 121 feet PSD, so the plant's permanent equipment would be expected to cope with this event. However, as required by the order, there is also a FLEX strategy to cope with a flooding event. There are two FLEX DGs pre-staged on the roof of the Unit 2 reactor building, which is about 30 feet above grade. One is needed for the FLEX strategy and the second is a spare (N+1). The FLEX alternate header pumps in the B core spray pump room are not susceptible to flooding and will be available for this event. The licensee stated in its FIP that a hurricane event is assumed to have greater than 48 hours of warning time and flooding is expected to persist above site grade for approximately 11 hours. The licensee also stated that necessary FLEX equipment, such as the FLEX service water pumps, will be moved from outside storage to flood protected areas such as inside the Unit 1 or Unit 2 reactor buildings. After the floodwaters recede, the FLEX equipment can be deployed.

3.2.3 Staff Evaluations

3.2.3.1 Availability of Structures, Systems, and Components (SSCs)

Guidance document NEI 12-06 provides guidance that the baseline assumptions have been established on the presumption that other than the loss of the ac power sources and normal access to the UHS, installed equipment that is designed to be robust with respect to design basis external events is assumed to be fully available. Installed equipment that is not robust is assumed to be unavailable. Below are the baseline assumptions for the availability of SSCs for core cooling during an ELAP caused by a BDBEE.

3.2.3.1.1 Plant SSCs

Core Cooling

Phase 1

The licensee's Phase 1 core cooling strategy relies on SRVs to control pressure and the RCIC and HPCI systems to inject makeup water into the RPV. In the FIP, Section 2.3.1 states that HPCI injection will be terminated as soon as the RCIC system is capable of controlling RPV level alone.

In the FIP, Section 2.3.4.2 describes the RCIC system as a safety-related system consisting of a steam turbine-driven pump, piping, valves, and controls that takes suction from the CST, or alternatively the suppression pool. It can operate independent of ac power; however, it requires 250 Vdc battery power for valves and small motors and 125 Vdc battery power for its logic (or control). In addition, based on battery sizing calculations described in FIP Section 2.3.1, the licensee determined RCIC would be available for at least 5 hours without any FLEX equipment support. In the FIP, Section 2.3.9.3 states that the suppression pool water supply is robust for all external hazards and the CST is seismically adequate (i.e., not Seismic Category I but expected to survive the design basis safe shutdown earthquake). However, the licensee relies on the suppression pool, instead of the CST, in its baseline Modular Accident Analysis Program (MAAP) analyses (see safety evaluation (SE) Section 3.10 for additional discussion of water sources). As described in Section 5.4.6 of the Updated Final Safety Analysis Report (UFSAR), the RCIC system and suppression pool are located in the reactor building, which is a Seismic Category I structure that protects the RCIC system and suppression pool from all external hazards. Therefore, the NRC staff finds the RCIC system, including the steam turbine-driven pump and suppression pool, are robust and are expected to be available at the start of an ELAP event consistent with NEI 12-06, Section 3.2.1.3.

In the FIP, Section 2.3.4.3 states that SRVs will automatically cycle to initially control reactor pressure. Afterwards, these valves are cycled by the operations staff to depressurize the RPV during a controlled cooldown. The SRVs require 125 Vdc battery power for control and compressed gas for operation. In the FIP, Section 2.3.1 states that PCIG receivers provide compressed air to the SRVs until they are depleted; after which individual accumulators supply compressed air. The licensee describes its analyses for accumulator capacity and battery life in FIP Section 2.3.1. Based on these analyses, the licensee determined the SRVs would be available for at least 5 hours without any FLEX equipment support. The SRVs and accumulators are safety related and are located in the reactor building, which protects them from all external hazards. Furthermore, the licensee describes that environmental qualifications for the SRV solenoid valves are not expected to be exceeded in FIP Section 2.5.1. Therefore, the NRC staff finds the SRVs and accumulators are robust and are expected to be available at the start of an ELAP event consistent with NEI 12-06, Section 3.2.1.3.

Phase 2

The licensee's Phase 2 strategy continues to use the suppression pool as the heat sink for SRV discharges and RCIC turbine steam exhaust. To ensure continued SRV functionality, the licensee will connect a portable compressor to the PCIG piping system. In addition, the licensee will use the portable diesel-driven FLEX pump to replenish the suppression pool with river water. If RCIC becomes unavailable, the licensee will use the motor-driven FLEX alternate header pump to provide high quality water through primary and alternate connections (See FIP Sections 2.3.5.3 and 2.3.9.1.). Alternatively, the licensee can use the diesel-driven FLEX pump to inject river water into the RPV through the SW system. The licensee plans to rely on the FLEX pumps, FLEX connection points, and water sources discussed in SE Sections 3.2.3.5, 3 3.7, and 3.10, respectively.

Phase 3

The licensee's Phase 3 core cooling strategy is to start up one ECCS division. As described in FIP Section 2.3.3, it will use four 4.16 kV NSRC generators to power the "A" Safety Auxiliaries Cooling System (SACS) pump and the "A" Residual Heat Removal (RHR) pump. In addition, a large diesel-driven pump will supply river water to cool the SACS heat exchanger. In the UFSAR, Table 3.2-1 indicates that the ECCS is Seismic Category I and is located in the reactor building which is a Category I structure. The reactor building protects the ECCS equipment from all external hazards. Therefore, the NRC staff finds the ECCS is robust and is expected to be available during an ELAP event consistent with NEI 12-06, Section 3.2.1.3.

3.2.3.1.2 Plant Instrumentation

The licensee's plan for HCGS is to monitor instrumentation in the main control room, and by alternate means if necessary, to support the FLEX cooling strategy. The instrumentation is powered by the station batteries and will be maintained available for indefinite coping via battery chargers powered by the FLEX diesel generators. A more detailed evaluation of the instrumentation power supply is contained in Section 3.2.3.6 of this SE.

As described in the HCGS FIP, in Sections 2.3.6 and 2.5.5, the following instrumentation will be relied upon to support the FLEX core cooling and inventory control strategy:

- Reactor vessel level (fuel zone), Channels A and B
- Reactor vessel level
- Reactor pressure
- Reactor vessel level (post-accident monitoring system)
- Reactor pressure (post-accident monitoring system)
- Suppression pool level (narrow range)
- Suppression pool level
- Suppression pool water temperature
- Suppression chamber pressure
- Suppression chamber temperature
- Drywell pressure (narrow and wide range)
- Drywell temperature

These instruments are monitored from the control room and are accessible to the operators throughout the event. The instrumentation identified by the licensee to support its core cooling strategy is consistent with the recommendations specified in the endorsed guidance of NEI 12-06.

Per the FIP, station batteries normally power the instrumentation. Following the initiation of the ELAP event, the battery power is extended by performing a load shed. Charging of the batteries will be initiated within 5 hours of the initiation of the ELAP event by means of a portable 480 Vac FLEX DG, which will energize 125 Vdc and 250 Vdc battery chargers. The FLEX generators will continue to provide power through the duration of the event. Additional backup generators will be available from the NSRC during Phase 3. Based upon the information provided by the licensee, the NRC staff understands that the critical instruments will be accessible continuously throughout the ELAP event.

In accordance with NEI 12-06 Section 5.3.3.1, guidelines for obtaining critical parameters locally are provided in associated FLEX support guidelines (FSGs). The licensee provides portable BDB equipment needed to operate local instrumentation. Additional guidance on obtaining critical parameters locally is contained in HC.OP-AM-TSC-0027, "Local Monitoring of Key Plant Parameters." Some critical parameters in the guidelines include reactor vessel level and pressure; suppression pool temperature and level; drywell pressure; condensate storage tank level; and primary containment hydrogen and oxygen concentration. The SFP level instruments are discussed in Section 4 below.

3.2.3.2 Thermal-Hydraulic Analyses

The licensee based its mitigating strategy for reactor core cooling in part on thermal-hydraulic analysis performed using Version 4 of the MAAP (MAAP4). Because the thermal-hydraulic analysis for the reactor core and containment during an ELAP event are closely intertwined, as is typical of BWRs, the licensee has addressed both in a single, coupled calculation. This dependency notwithstanding, the NRC staff's discussion in this section of the SE solely focuses on the licensee's analysis of reactor core cooling. The review of the licensee's analysis of containment thermal-hydraulic behavior is provided in Section 3.4.4.2 of this evaluation.

The MAAP is an industry-developed, general-purpose thermal-hydraulic computer code that has been used to simulate the progression of a variety of light water reactor accident sequences, including severe accidents such as the Fukushima Dai-ichi event. Initial code development began in the early 1980s, with the objective of supporting an improved understanding of and predictive capability for severe accidents involving core overheating and degradation in the wake of the accident at Three Mile Island Nuclear Station, Unit 2. Currently, maintenance and development of the code is carried out under the direction of the Electric Power Research Institute (EPRI).

To provide analytical justification for their mitigating strategies in response to Order EA-12-049, a number of licensees for BWRs and pressurized-water reactors (PWRs) completed analysis of the ELAP event using MAAP4. Although MAAP4 and predecessor code versions have been used by industry for a range of applications, such as the analysis of severe accident scenarios and probabilistic risk analysis (PRA) evaluations, the NRC staff had not previously examined the code's technical adequacy for performing best-estimate simulations of the ELAP event. In particular, due to the breadth and complexity of the physical phenomena within the code's calculation domain, as well as its intended capability for rapidly simulating a variety of accident scenarios to support PRA evaluations, the NRC staff observed that the MAAP code makes use of a number of simplified correlations and approximations that should be evaluated for their applicability to the ELAP event. Therefore, in support of the reviews of licensees' strategies for ELAP mitigation, the NRC staff audited the capability of the MAAP4 code for performing thermal-hydraulic analysis of the ELAP event for both BWRs and PWRs. The NRC staff's audit review involved a limited review of key code models, as well as confirmatory analysis with the TRACE code to obtain an independent assessment of the predictions of the MAAP4 code.

To support the NRC staff's review of the use of MAAP4 for ELAP analyses, in June 2013, EPRI issued a technical report entitled "Use of Modular Accident Analysis Program (MAAP) in Support of Post-Fukushima Applications." The document provided general information concerning the code and its development, as well as an overview of its physical models, modeling guidelines, validation, and quality assurance procedures.

Based on the NRC staff's review of EPRI's June 2013 technical report, as supplemented by further discussion with the code vendor, audit review of key sections of the MAAP code documentation, and confirmation of acceptable agreement with NRC staff simulations using the TRACE code, the NRC staff concluded that, under certain conditions, the MAAP4 code may be used for best-estimate prediction of the ELAP event sequence for BWRs.

The NRC staff issued an endorsement letter dated October 3, 2013 [Reference 28], which documented these conclusions and identified specific limitations that BWR licensees should address to justify the applicability of simulations using the MAAP4 code for demonstrating that the requirements of Order EA-12-049 have been satisfied.

During the audit process, the NRC staff verified that the licensee's MAAP4 calculation, along with an associated addendum, addressed the limitations from the NRC staff's endorsement letter. The licensee utilized the generic roadmap and response template that had been developed by EPRI to support consistency in individual licensee's responses to the limitations from the endorsement letter. In particular, based upon a review of the MAAP4 calculation documentation, the staff concluded that appropriate inputs and modeling options had been selected for the code parameters expected to have dominant influence for the ELAP event. The NRC staff further observed that the limitations imposed in the endorsement letter, particularly those concerning the RPV collapsed liquid level being maintained above the reactor core and the primary system cooldown rate being maintained within Technical Specification limits, were satisfied. Specifically, the licensee's analysis calculated that HCGS would maintain the collapsed liquid level in the reactor vessel above the top of the active fuel region throughout the analyzed ELAP event. The licensee calculated that the minimum RPV water level above the top of active fuel is approximately 3.5 feet and occurs immediately following the event initiation. By maintaining the reactor core fully covered with water, adequate core cooling is assured for this event. Additionally, PSEG's fulfillment of the endorsement letter condition regarding the primary system cooldown rate signifies that thermally induced volumetric contraction and other changes in primary system thermal-hydraulic conditions should proceed relatively slowly with time, which supports the NRC staff's confidence in the predictions of the MAAP4 code. Furthermore, that the licensee should be capable of maintaining the entire reactor core submerged throughout the ELAP event is consistent with the staff's expectation that the licensee's flow capacity for primary makeup (i.e., installed RCIC pump and, subsequently, FLEX pumps) should be sufficient to support adequate heat removal from the reactor core during the analyzed ELAP event, including potential losses due to expected primary leakage.

Therefore, based on the evaluation above, the NRC staff concludes that the licensee's analytical approach should appropriately determine the sequence of events for reactor core cooling, including time-sensitive operator actions, and evaluate the required equipment to mitigate the analyzed ELAP event, including pump sizing and cooling water capacity.

3.2.3.3 Recirculation Pump Seals

An ELAP event would result in the interruption of cooling to the recirculation pump seals, potentially resulting in increased leakage due to the distortion or failure of the seals, elastomeric O-rings, or other components. Sufficient primary make-up must be provided to offset recirculation pump seal leakage and other expected sources of primary leakage, in addition to removing decay heat from the reactor core.

The licensee's calculations for HCGS assumed a total leakage rate of 61 gallons per minute (gpm) at the normal RPV operating pressure. This leakage rate includes 18 gpm per recirculation pump seal in accordance with evaluations that were conducted to support NRC Generic Letter 91-07. In addition, the licensee's calculation assumed an additional primary system leakage rate equal to the Technical Specification LCO 3.4.3.2 limit of 25 gpm for identified leakage. Thus, between the two recirculation pumps and the additional identified primary system leakage, the total primary leakage rate assumed for PSEG during the ELAP event was 61 gpm at normal operating reactor pressure.

During the audit, the NRC staff discussed recirculation pump seal leakage with the licensee and requested that the licensee justify the applicability of the assumed leakage rate to the ELAP event. In its FIP, the licensee stated that the seal leakage rate and total reactor coolant system (RCS) leakage rate will be proportional to the RPV pressure. The licensee performed calculations to determine the limiting RPV pressure beyond which the FLEX alternate header pump would not be capable of supplying the required flow. Based on HCGS analysis the limiting flow rate for the FLEX alternate header pump occurred at an RPV pressure of 145 psig when taking suction from the suppression pool and 161 psig when taking suction from the CST. At these pressures and conditions, the FLEX alternate header pump is able to provide a minimum flow rate of 235 gpm (no earlier than 5 hours after initiation of the ELAP event). This required flow considers the flow required to replace evaporative losses as well as leakage losses. Further depressurization of the RPV would result in a reduction in the leakage loss term.

Considering the above factors, the NRC staff concludes that the leakage rate of 18 gpm is reasonable. Gross seal failures are not anticipated to occur during the postulated ELAP event. As is typical of the majority of U.S. BWRs, HCGS has an installed steam-driven pump (i.e., RCIC) capable of injecting into the primary system at a flow rate well in excess of the primary system leakage rate expected during an ELAP event, and the other pumps used for core cooling in its FLEX strategy have a similar functional capability. As discussed previously, at the limiting pressure, the FLEX alternate header pump (the lower capacity FLEX pump) is able to inject at a rate that maintains adequate margin.

Based upon the discussion above, the NRC staff concludes that the recirculation pump seal leakage rates assumed in the licensee's thermal-hydraulic analysis may be applied to the beyond-design-basis ELAP event for the site.

3.2.3.4 Shutdown Margin Analyses

As described in HCGS's UFSAR, the control rods provide adequate shutdown margin under all anticipated plant conditions, even with the assumption that the highest-worth control rod remains fully withdrawn. In PSEG Technical Specification Section 1.1, "Definitions," it is further clarified that shutdown margin is to be calculated for a cold, xenon-free condition to ensure that the most reactive core conditions are bounded.

Based on the NRC staff's audit review, the licensee's ELAP mitigating strategy maintains the reactor within the envelope of conditions analyzed by the licensee's existing shutdown margin calculation. Furthermore, the existing calculation is conservative because the guidance in NEI 12-06 permits analyses of the beyond-design-basis ELAP event to assume that all control rods fully insert into the reactor core.

Therefore, based on the evaluation above, the NRC staff concludes that the sequence of events in the proposed mitigating strategy should result in acceptable shutdown margin for the analyzed ELAP event.

3.2.3.5 FLEX Pumps and Water Supplies

The licensee relies on two FLEX pumps during Phase 2 to support core cooling and RPV inventory control. When RCIC can no longer function (e.g., due to insufficient steam flow), water from the CST or suppression pool can be injected into the RPV using a pre-staged electric motor-driven FLEX alternate header pump. Alternatively, river water can be injected using a portable diesel-driven FLEX pump. This pump can also replenish the suppression pool using river water. In the FIP, Table 1 states the performance criteria (e.g., flow rate, discharge pressure, and head) for the Phase 2 FLEX pumps. Also, FIP Table 2 shows the performance criteria for NSRC-supplied FLEX diesel-driven pumps that are part of the licensee's Phase 3 core cooling strategy. See SE Section 3.2.3.1.1 for a discussion of the licensee's core cooling strategies and SE Section 3.10 for a discussion of the availability and robustness of each water source.

As described in FIP Section 2.3.9.1, the FLEX alternate header pump has a nominal flow rate of 450 gpm at 180 psi discharge pressure. The licensee performed calculation H-1-FLX-MDC-4022 (including revision 0a), "FLEX Hydraulic Model," to determine the fluid system hydraulic performance. This calculation includes a flow acceptance criterion of 235 gpm to keep RPV level above the top of active fuel. The licensee determined that the FLEX alternate header pump can provide the required makeup flow rate when the pump takes suction from either the CST or the suppression pool. In addition, the licensee calculated the maximum RPV pressure for which this pump can supply the required flow rate and determined the calculated pressure bounds the pressure for which the pump is credited. In the FIP, Section 2.3.9.1 states that two FLEX alternate header pumps are available. One is a spare pump which satisfies the N+1 criteria of NEI 12-06. These pumps are pre-staged in the Core Spray Pump Room (Room 4104) of the Unit 1 reactor building which is a Seismic Category I structure. It protects the FLEX alternate header pumps from all external hazards.

In the FIP, Sections 2.3.2 and 2.3.9.2 describe the diesel-driven FLEX pump, and FIP Table 1 shows that this pump has a nominal flow rate of 1500 gpm at 350 feet (ft) of total dynamic head. Calculation H-1-FLX-MDC-4022 states that the diesel-driven FLEX pump provides long-term makeup flow to the RPV using the Delaware River as the suction source. For a minimum pump speed of 1200 rpm, the calculation determined that the pump can supply the required makeup flow of at least 235 gpm to the RPV using either the "A" or "B" hose discharge header. In the FIP, Section 2.18.6 describes the licensee's N+1 strategy in relation to this pump. Salem Generating Station (Salem) and HCGS are co-located on a common site, and FIP Table 1 states that three FLEX pumps are available at the site, one in each of the three outdoor storage areas. The licensee meets the N+1 requirement by providing one spare in addition to the one pump required for each station. In the FIP, Section 2.6.3 states that these pumps are stored outdoors and are not missile protected. However, they are separated by a significant distance to ensure at least N pumps will be available, as discussed in section 3.6.1.3 of this SE. Furthermore, FIP Section 2.6.2 states that the diesel-driven FLEX pumps will be moved from their normal outdoor storage locations to the flood protected Unit 2 reactor building before the arrival of a hurricane.

The staff confirmed that the flow rates and pressures evaluated in the hydraulic analyses were also used in HC-MISC-005, "MAAP Analysis to Support FLEX Initial Strategy." During the onsite audit, the staff conducted a walk down of the hose deployment routes for the above FLEX pumps to confirm the evaluations of the pump staging locations, hose distance runs, and connection points as described in the above hydraulic analyses and the FIP.

Based on the staff's review of the FLEX pumping capabilities at HCGS, as described in the above hydraulic analyses and the FIP, the licensee has demonstrated that its pre-staged and portable FLEX pumps should perform as intended to support core cooling and RCS inventory control during an ELAP event, consistent with NEI 12-06, Section 11.2.

3.2.3.6 Electrical Analyses

The licensee's electrical strategies provide power to the equipment and instrumentation used to mitigate the ELAP and LUHS. The electrical strategies described in the FIP are practically identical for maintaining or restoring core cooling, containment, and SFP cooling, except as noted in Sections 3.3.4.4 and 3.4.4.4 of this SE.

The NRC staff reviewed the licensee's FIP conceptual, electrical, single-line diagrams and the summary of calculations for sizing the FLEX generators and station batteries. The NRC staff also reviewed the licensee's evaluations that addressed the effects of temperature on the electrical equipment credited in the FIP as a result of the loss of heating, ventilation, and air conditioning (HVAC) caused by the event.

According to the licensee's FIP, operators would declare an ELAP following a loss of offsite power, EDGs, and any alternate ac source. The plant's indefinite coping capability is attained through the implementation of pre-determined FLEX strategies that are focused on maintaining or restoring key plant safety functions. A safety function-based approach provides consistency with, and allows coordination with, existing plant emergency operating procedures (EOPs). The FLEX strategies are implemented in support of EOPs using FSGs.

During the first phase of an ELAP event, Hope Creek would rely on the safety-related Class 1E batteries to provide power to key instrumentation and applicable dc components. The Hope Creek Class 1E station batteries and associated dc distribution systems are located within safety-related structures designed to meet applicable design-basis external hazards. The licensee's procedure HC.OP-AB.ZZ-0135(Q), "Station Blackout // Loss of Offsite Power// Diesel Generator Malfunction," Revision 42, directs operators to conserve dc power during the event by stripping non-essential loads. Operators will strip or shed unnecessary loads to extend battery life until backup power is available (Phase 2). The plant operators would complete load shedding within 1.5 hours from the onset of an ELAP/LUHS event.

Hope Creek has four Class 1E 125 Vdc station batteries (1AD411, 1BD411, 1CD411, 1DD411). Batteries 1AD411 and 1BD411 are credited for FLEX. Hope Creek also has two Class 1E 250 Vdc batteries that are credit for FLEX (10D421 - HPCI Battery and 10D431 - RCIC Battery). The 125 Vdc and 250 Vdc batteries were manufactured by C&D Technologies. The 125 Vdc batteries are model LCU-27 with a capacity of 1950 ampere-hours (AH). The battery coping times for batteries 1AD411, 1BD411, 1CD411, and 1DD411 are 5.0 hours, 5.1 hours, 6.8 hours, and 24 hours, respectively. The 250 Vdc HPCI battery (10D421) is model KCR-21 with a capacity of 825 AH. The 250 Vdc RCIC battery (10D431) is model KCR-9 with a capacity of 330 AH. The battery coping times for batteries 10D421 and 10D431 are 14.5 and 9.0 hours, respectively.

The NEI White Paper, "EA-12-049 Mitigating Strategies Resolution of Extended Battery Duty Cycles Generic Concern," (Agencywide Documents Access and Management System (ADAMS) Accession No. ML13241A186) provides guidance for calculating extended duty cycles of batteries (i.e., beyond 8 hours). This paper was endorsed by the NRC (ADAMS Accession No. ML13241A188). In addition to the White Paper, the NRC sponsored testing at Brookhaven National Laboratory that resulted in the issuance of NUREG/CR-7188, "Testing to Evaluate

Extended Battery Operation in Nuclear Power Plants," in May of 2015. The testing provided additional validation that the NEI White Paper method was technically acceptable. The NRC staff reviewed the licensee's battery calculations and confirmed that they had followed the guidance in the NEI White Paper.

The NRC staff reviewed the licensee's dc coping calculations E-4.6(Q), "Hope Creek 125 VDC Beyond Design Base Event Battery Sizing Calculation," Revision 1 and E-5.2(Q), "Hope Creek 250 VDC Beyond Design Basis Event Battery Sizing Calculation," Revision 0, which verified the capability of the dc system to supply power to the required loads during the first phase of the Hope Creek FLEX mitigation strategy plan for an ELAP. The licensee's evaluation identified the required loads and their associated ratings (amperes (A) and minimum required voltage) and the non-essential loads that would be shed within 1.5 hours to ensure battery operation for at least 5 hours.

Based on the staff's review of the licensee's analysis and procedures, and the battery vendor's capacity and discharge rates for the Class 1E station batteries, the NRC staff finds that the Hope Creek dc systems have adequate capacity and capability to power the loads required to mitigate the consequences during Phase 1 of an ELAP, provided that necessary load shedding is completed within the times assumed in the licensee's analysis.

The licensee's Phase 2 strategy includes repowering the Class 1E battery chargers within 5 hours after initiation of an ELAP to maintain availability of instrumentation to monitor key parameters. Prior to depletion of the 125 Vdc Class 1E batteries and 250 Vdc batteries, operators would repower the battery chargers using one of the permanently installed 480 Vac 600 kilowatt (kW) FLEX DGs located on the Unit 2 reactor building roof. Loads other than the Class 1E battery chargers which could be powered by a FLEX DG in Phase 2 include the FLEX alternate header pump, FLEX air compressor, motor-operated valves, fuel oil transfer pumps, SFP level instrumentation, and the filtration, recirculation, and ventilation system (FRVS) vent fan. Hope Creek has three 480 Vac 600 kW FLEX DGs. Only one of the FLEX DGs is required for the Phase 2 electrical strategy.

During a tornado event, if either, or both, of the 600 kW DGs installed on the Unit 2 reactor building roof became unavailable or otherwise out of service, the other ("N+1") 600 kW DG (stored a significant distance away from the two FLEX DGs on the Unit 2 reactor building roof, as discussed in section 3.6.1.3 of this SE) would be deployed to continue to support the required loads. All three 600 kW DGs are identical, thus ensuring electrical compatibility and sufficient electrical capacity in an instance where substitution is required. During a BDBEE other than a tornado event, the 600 kW DGs on the Unit 2 reactor building roof alone provide "N" and "N+1" capability since they are identical and interchangeable. Since the 600 kW DGs are identical and interchangeable, the NRC staff finds that the licensee has met the provisions of NEI 12-06 for spare equipment capability regarding the Phase 2 FLEX generators.

The NRC staff reviewed licensee calculation E-15.16, "Hope Creek FLEX Electrical System Loading Analysis," Revision 0, conceptual single line diagrams, and the separation and isolation of the FLEX DGs from the EDGs. Based on the NRC staff's review of the calculation (E-15.16), the minimum required loads for the licensee's Phase 2 600 kW FLEX DG is 364.1 kW. The licensee's calculations took the FLEX cable lengths into consideration (i.e., ensured that the voltage drop did not exceed the minimum voltage required at the limiting component). Based on its review of the licensee's calculation, the NRC staff finds that one 600 kW FLEX DG is adequate to support the electrical loads required for the licensee's Phase 2 strategies.

For Phase 3, the licensee plans to continue the Phase 2 coping strategy with additional assistance provided from offsite equipment/resources. The offsite resources that will be provided by an NSRC includes four 1-megawatt (MW) 4160 Vac CTGs, one 1000 kW 480 Vac CTG, and distribution panels (including cables and connectors). According to licensee calculation E-15.16, the loads to be powered by the Phase 3 CTGs would total 1627.1 kW. These loads fall within the rating of the 4160 Vac Phase 3 CTGs. The Phase 3 4160 Vac CTGs would supply power for a safety auxiliary cooling pump, an RHR pump, and some of the Phase 2 loads. Based on its review, the NRC staff finds that the equipment being supplied from either of the NSRCs has sufficient capacity and capability to supply the required loads during Phase 3.

Based on its review, the NRC staff finds that the plant batteries used in the strategy should have sufficient capacity to support the licensee's strategy, and that the FLEX DGs and turbine generators that the licensee plans to use should have sufficient capacity and capability to supply the necessary loads during an ELAP event.

3.2.4 Conclusions

Based on this evaluation, the NRC staff concludes that the licensee has developed guidance that should maintain or restore core cooling and RCS inventory during an ELAP event consistent with NEI 12-06 guidance, as endorsed by JLD-ISG-2012-01, and should adequately address the requirements of the order.

3.3 Spent Fuel Pool Cooling Strategies

In NEI 12-06, Table 3-1 and Appendix C summarize an acceptable approach consisting of three separate capabilities for the SFP cooling strategies. This approach describes using a portable injection source to provide the capability for 1) makeup via hoses on the refueling floor capable of exceeding the boil-off rate for the design basis heat load; 2) makeup via connection to spent fuel pool cooling piping or other alternate location capable of exceeding the boil-off rate for the design basis heat load; and 3) spray via portable monitor nozzles from the refueling floor using a portable pump capable of providing a minimum of 200 gpm per unit (250 gpm if overspray occurs). During the event, the licensee selects the SFP makeup method to use based on plant conditions. This approach also requires a strategy to mitigate the effects of steam from the SFP, such as venting.

As described in NEI 12-06, Section 3.2.1.7, and JLD-ISG-2012-01, Section 2.1, strategies that must be completed within a certain period of time should be identified and a basis that the time can be reasonably met should be provided. In NEI 12-06, Section 3 provides the performance attributes, general criteria, and baseline assumptions to be used in developing the technical basis for the time constraints. Since the event is beyond design basis, the analysis used to provide the technical basis for time constraints for the mitigation strategies may use nominal initial values (without uncertainties) for plant parameters, and best-estimate physics data. All equipment used for consequence mitigation may be assumed to operate at nominal setpoints and capacities. In NEI 12-06, Section 3.2.1.2 describes the initial plant conditions for the at-power mode of operation; Section 3.2.1.3 describes the initial conditions; and Section 3.2.1.6 describes SFP initial conditions.

In NEI 12-06, Section 3.2.1.1 provides the acceptance criterion for the analyses serving as the technical basis for establishing the time constraints for the baseline coping capabilities to maintain SFP cooling. The criterion is to keep the fuel in the SFP covered with water. The ELAP causes a loss of cooling in the SFP. As a result, the pool water will heat up and eventually boil off. The licensee's response is to provide makeup water. The timing of operator actions and the required makeup rates depend on the decay heat level of the fuel assemblies in the SFP. The sections below address the response during operating, pre-fuel transfer, or post-fuel transfer operations. The effects of an ELAP with full core offload to the SFP is addressed in Section 3.11.

3.3.1 Phase 1

The licensee stated in its FIP that no actions are required during ELAP Phase 1 for SFP makeup because the time to boil is sufficient to enable deployment of Phase 2 equipment. Adequate SFP inventory exists to provide radiation shielding for personnel well beyond the time of boiling. The licensee will monitor SFP water level using reliable SFP level instrumentation installed per Order EA-12-051.

3.3.2 Phase 2

In Technical Evaluation 70127346-0230, the licensee estimates the refueling floor would remain habitable for 37 hours following a BDBEE. To reduce condensation and temperature at the SFP refueling floor and permit personnel access, a vent pathway is established in the SFP area. In the FIP, Section 2.4.4.2 states that during Phase 2 a filtration, recirculation, and ventilation system (FRVS) vent fan will be repowered by the FLEX electrical system to exhaust air out of the reactor building and through the FRVS vent stack.

In addition, during Phase 2, SFP makeup paths will be established. In the FIP, Section 2.4.2 describes fill methods using either the diesel-driven FLEX pump or the electric motor-driven FLEX alternate header pump. The diesel-driven FLEX pump can supply river water to the SFP via the SW header. The FLEX alternate header pump can supply water from the CST (if available) or the torus. The FLEX alternate header pump can discharge to three possible flow paths: 1) to the FLEX standpipe in the northwest stairwell of the reactor building truck bay, and inject to the SFP via a hose staged on the refueling floor; 2) to the FLEX standpipe to the reactor building 168 ft elevation, and then connect to the existing SFP spray nozzle; and 3) from the FLEX injection header to the service water emergency fill line to the SFP in the reactor auxiliary cooling system (RACS) room on the 77 ft elevation of the reactor building. See SE Section 3.7.3.1 for a discussion of connection points for SFP makeup and SE Section 3.10 for a discussion of water sources.

3.3.3 Phase 3

In the FIP, Section 2.4.3 states that no additional Phase 3 strategies are required. However, to meet the order requirements, NSRC equipment must be available during Phase 3 for SFP cooling. In the FIP, Table 2, "FLEX Equipment from NSRC," shows that diesel-driven pumps and mobile water treatment equipment are available for SFP makeup.

3.3.4 Staff Evaluations

3.3.4.1 Availability of Structures, Systems, and Components

3.3.4.1.1 Plant SSCs

Condition 6 of NEI 12-06, Section 3.2.1.3, states that permanent plant equipment contained in structures with designs that are robust with respect to seismic events, floods, and high winds, and associated missiles, are available. In addition, Section 3.2.1.6 states that the initial SFP conditions are: 1) all boundaries of the SFP are intact, including the liner, gates, transfer canals, etc., 2) although sloshing may occur during a seismic event, the initial loss of SFP inventory does not preclude access to the refueling deck around the pool and 3) SFP cooling system is intact, including attached piping.

The NRC staff reviewed the licensee's calculation on habitability on the SFP refueling floor in Technical Evaluation 70127346-0230, "Hope Creek Spent Fuel Pool Time to Boil and Level Depletion Rate." As described in Calculation EC-0010, "SFP Evaporation Rates, Heat-Up Rates and Fuel Uncover Times - EPU," the SFP will boil in approximately 19.62 hours at the maximum normal heat load. Action Item 12 in FIP Table 3 (i.e., the licensee's sequence of events timeline) indicates that operators will install a FLEX hose jumper to complete the FLEX flow path to the SFP within 13 hours from event initiation. This action is done well within the time period for which the SFP area remains habitable.

In this SE, Section 3.3 describes the licensee's SFP cooling strategies. The licensee's Phase 1 SFP cooling strategy does not require any operator actions other than monitoring SFP level using installed instrumentation. During Phase 2, a vent pathway will be established in the reactor building using the FRVS vent fan which is repowered by the FLEX electrical system. In addition, during Phase 2, the licensee will use the FLEX alternate header pump with suction from the CST (if available) or torus, to supply water to the SFP. Alternatively, it will use the diesel-driven FLEX pump to supply river water to the SFP via the SW header. The NRC staff's evaluation of the robustness and availability of FLEX connection points for the FLEX pumps is discussed in SE Section 3.7.3.1 below. Furthermore, the staff's evaluation of the robustness and availability of the UHS for an ELAP event is discussed in SE Section 3.10.3.

3.3.4.1.2 Plant Instrumentation

In its FIP, the licensee stated that the instrumentation for SFP level will meet the requirements of Order EA-12-051. Furthermore, the licensee stated that these instruments will have initial local battery power with the capability to be powered from the FLEX DGs. The NRC staff's review of the SFP level instrumentation, including the primary and back-up channels, the display to monitor the SFP water level, and environmental qualifications to operate reliably for an extended period, is discussed in Section 4 of this SE.

3.3.4.2 Thermal-Hydraulic Analyses

Calculation EC-0010, "SFP Evaporation Rates, Heat-Up Rates and Fuel Uncover Times - EPU," determines SFP heatup during refueling scenarios. With a batch offload for refueling completed 8 days after shutdown, the SFP will boil in approximately 19.62 hours. With a full core offload completed 10 days after shutdown, the SFP will boil in about 6.89 hours. For these maximum heat loads and without operator action, the SFP will boil to a level 15 feet above the fuel about 57 hours into the event for an ELAP occurring during normal refueling operations and about 21.4 hours into the event for an ELAP occurring during full core offload refueling operations. At that water level, there is still adequate water to provide radiation shielding to allow personnel access to the refueling floor.

In the FIP, Section 2.4.7 states that the SFP makeup requirements during ELAP events are based on the maximum design-basis heat load in the SFP. Calculation EC-0010 includes two bounding refueling scenarios specific to the SFP for a thermal power level of 3,840 MWt, which is the current authorized power level for HCGS. It includes (1) a maximum normal refueling heat load scenario (batch off-load with full SFP and 8-day fuel decay) and (2) a maximum refueling heat load scenario (full core off-load with a full SFP and 10-day fuel decay). The heat loads, boil-off times, and makeup rates are shown in the following table.

	Heat Load	Time to boil to top of fuel	Makeup rate
Case 1	17.6 million Btu/hr	131 hrs (5.47 days)	36.6 gpm
Case 2	46.4 million Btu/hr	49 hrs (2.06 days)	97.5 gpm

Calculation H-1-FLX-MDC-4022, "FLEX Hydraulic Model" is a hydraulic analysis that includes each FLEX pump's alignment to the SFP. This analysis shows that either the FLEX alternate header pump or the diesel-driven FLEX pump will provide at least the required makeup rate to the SFP (See SE Section 3.3.4.3 for additional discussion.). Therefore, consistent with the guidance in NEI 12-06, Section 3.2.1.6, the staff finds the licensee has sufficient SFP makeup capability to ensure an adequate water level in the SFP at the maximum design-basis SFP heat load.

3.3.4.3 FLEX Pumps and Water Supplies

As described in FIP Section 2.4.8.1, after 44 hours, SFP makeup is anticipated to be required. During Phase 2, the licensee's SFP cooling strategy relies on FLEX pumps to supply SFP makeup. One pump that the licensee relies on is an electric motor-driven FLEX alternate header pump. This pump is shared between the core cooling and SFP functions, and therefore, it is also discussed in SE Section 3.2.3.5. In the FIP, Sections 2.3.9.1, 2.4.8.1, and Table 1 describe the pump's hydraulic performance criteria (e.g., flow rate and discharge pressure). This pump has a nominal flow rate of 450 gpm at 180 psig discharge pressure. The FLEX alternate header pumps are pre-staged in the Seismic Category I reactor building as an alternative to NEI 12-06 criteria for portable FLEX equipment. Two pumps are pre-staged to satisfy the N+1 criteria of NEI 12-06. As an alternative to the FLEX alternate header pump, a diesel-driven FLEX pump can supply river water to the SFP via the SW header.

In the FIP, Table 1 shows that the diesel-driven FLEX pump is rated at 1500 gpm at 350 feet of total dynamic head. Salem Units 1 and 2 share a common site and FLEX equipment with HCGS. Three diesel-driven FLEX pumps are located on site to satisfy the NEI N+1 criteria. The NRC staff also notes that the performance criteria shown in FIP Table 2 for diesel-driven FLEX pumps supplied from the NSRC in Phase 3 would allow these pumps to fulfill the mission of onsite FLEX pumps if the onsite FLEX pumps were to fail.

The licensee's hydraulic analysis is included in Calculation H-1-FLX-MDC-4022, "FLEX Hydraulic Model." This analysis (including minor revision 0a to this analysis) shows that the FLEX alternate header pump can provide a makeup rate of almost 400 gpm and the diesel-driven FLEX pump can provide a makeup rate of more than 250 gpm. These rates exceed the maximum SFP makeup requirements shown in SE Section 3.3.4.2. Furthermore, the NRC staff finds the licensee's hydraulic analysis is consistent with NEI 12-06, Section 11.2. Therefore, the NRC staff finds the FLEX equipment is capable of supporting the SFP cooling strategy, and it is expected to be available during an ELAP event (See SE Section 3.2.3.5 for a discussion of the storage of the FLEX pumps and their protection from external hazards).

3.3.4.4 Electrical Analyses

The licensee's Phase 1 electrical strategy is to monitor SFP level using installed instrumentation (the capability of this instrumentation is described in Section 4 of this SE). In its FIP, the licensee stated that SFP level instrumentation has a backup battery capacity that will provide power to the instrumentation for 72 hours, if necessary.

The licensee's Phase 2 electrical strategy is to repower SFP level instrumentation and the motor-driven FLEX alternate header pump using a 600 kW FLEX DG. Procedure HC.OP-EO.ZZ-0401 (Q), "FLEX Electrical – Phase 2," Revision 2, provides guidance for powering SFP level instrumentation and the motor-driven FLEX alternate header pump using a Phase 2 600 kW FLEX DG.

The licensee's Phase 3 strategy is to continue with the Phase 2 strategy and use equipment supplied by an NSRC as a backup.

The staff reviewed licensee calculation E-15.16 and determined that the 600 kW FLEX DG should have sufficient capacity and capability to supply SFP level instrumentation and the motor-driven FLEX alternate header pump during Phase 2. The NRC staff also finds that the 4160 Vac CTGs being supplied by an NSRC have adequate capacity and capability to supply the loads during Phase 3 of an ELAP, if necessary.

3.3.5 Conclusions

Based on this evaluation, the NRC staff concludes that the licensee has developed guidance that, if implemented appropriately, should maintain or restore SFP cooling following an ELAP consistent with NEI 12-06 guidance, as endorsed by JLD-ISG-2012-01, and should adequately address the requirements of the order.

3.4 Containment Function Strategies

NEI 12-06, Table 3-1, provides some examples of acceptable approaches for demonstrating the baseline capability of the containment strategies to effectively maintain containment functions during all phases of an ELAP event. One approach is for a licensee to perform an analysis demonstrating that containment pressure control is not challenged. Hope Creek has a General Electric BWR with a Mark I containment.

The licensee performed a containment evaluation, HC-MISC-005, "MAAP Analysis to Support FLEX Initial Strategy," which was based on the boundary conditions described in Section 2 of NEI 12-06. The calculation analyzed the strategy of venting the torus to maintain containment pressure below the design limit and concluded that the containment parameters of pressure and temperature remain well below the respective UFSAR Section 6.2, Table 6.2-1 design limits of 62 psig for the drywell and for the suppression chamber, and 340 °F for the drywell and 310 °F for the suppression chamber for more than 96 hours. From its review of the evaluation, the NRC staff noted that the required actions to maintain containment integrity and required instrumentation functions have been developed, and are summarized below.

3.4.1 Phase 1

The FIP states that during Phase 1, primary containment integrity is maintained by normal design features of the containment, such as the containment isolation valves. In accordance with NEI 12-06, the containment is assumed to be isolated following the event. The SRVs and the HCVS are used to protect containment. Core decay heat will be vented from the RPV to the torus water through the SRVs. The torus will be vented through the HCVS to mitigate the torus water temperature rise. Torus venting via the HCVS will maintain containment below design limits and within limits which permit continued use of RCIC. The EOPs HC.OP-EO.ZZ-0102, "Containment Control," and HC.OP-EO.ZZ-0106, "Containment Control – HPCI /RCIC Only," initiate venting via EOP HC.OP-EO.ZZ-0318, "Containment Venting." Procedure HC.OP-AB.ZZ-0135 directs the operators to connect the HCVS nitrogen supply using HC.OP-EO.ZZ-0318 within 4 hours of a station blackout (SBO). The MAAP analyses in HC-MISC-005 shows torus water temperature reaches 200 °F in approximately 4.1 hours. Torus venting in this time frame limits the torus water temperature peak to approximately 250 °F.

3.4.2 Phase 2

The Phase 2 strategy is to continue venting the torus through the HCVS to maintain containment within design temperature and pressure limits.

A portable compressor will be connected to the PCIG piping system using HC.OP-EO.ZZ-0407, "FLEX SRV Air Compressor," to assure continued SRV functionality during Phase 2. This portable compressor is powered by the 480 Vac supply provided by the FLEX generator. Suppression pool make-up water will be provided from the CST, or the Delaware River, by FLEX pumps, as discussed in Section 3.2.3.5, "FLEX Pumps and Water Supplies."

3.4.3 Phase 3

The FIP states that the Phase 3 FLEX equipment to maintain containment is the same as for maintaining core cooling. Four 4.16 kV generators from an NSRC will provide adequate power to energize one safety division and initiate core cooling using RHR with adequate margin remaining to begin torus water and SFP cooling.

The FIP shows that Hope Creek has strategies to maintain containment within design parameters using equipment available in all three Phases identified in the order.

3.4.4 Staff Evaluations

3.4.4.1 Availability of Structures, Systems, and Components

Guidance document NEI 12-06 baseline assumptions have been established on the presumption that other than the loss of the ac power sources and normal access to the UHS, installed equipment that is designed to be robust with respect to design-basis external events is assumed to be fully available. Installed equipment that is not robust is assumed to be unavailable. Below are the baseline assumptions for the availability of SSCs for maintaining containment functions during an ELAP.

3.4.4.1.1 Plant SSCs

Containment

The containment system consists of a drywell and a toroidal suppression chamber (the terms suppression chamber, torus, and wetwell are used interchangeably at HCGS). Containment is designed as a Seismic Category I structure. Seismic Category I SSCs are designed and constructed to remain functional following the effects of a safe shutdown earthquake (SSE). The containment is located in the Seismic Category I reactor building. The reactor building also provides protection from wind generated missiles.

Hardened Containment Vent System (HCVS)

Hope Creek previously installed a hardened wetwell vent in response to NRC Generic Letter 89-16, "Installation of a Hardened Wetwell Vent." The licensee upgraded the HCVS to meet the requirements of Phase 1 of Order EA-13-109, "Order Modifying Licenses with Regard to Reliable Hardened Containment Vents Capable of Operation Under Severe Accidents". The vent is sized to pass the steam/energy at a nominal capacity of at least 1 percent thermal power while maintaining the containment pressure below the design limits. The HCVS is considered to be seismically reliable and robust per the guidance in NEI 12-06. The HCVS has been analyzed for potential damage from tornado generated missiles.

Safety Relief Valves

The SRVs provide overpressure protection for the RCS. They open for RCS depressurization operation. The steam discharged heats up the suppression pool in the torus. The valves can be remotely operated from the main control room. The SRVs are seismic Category I components and are protected from tornadoes by their location inside the containment structure, with their control systems protected by the reactor building.

Based on these design qualifications, the containment, the HCVS, and the necessary support equipment credited in the strategy are robust, as defined by NEI 12-06, and should be available following an ELAP-inducing event.

3.4.4.1.2 Plant Instrumentation

In NEI 12-06, Table 3-1 specifies that containment pressure, suppression pool level, and suppression pool temperature are key containment parameters which should be monitored by repowering the appropriate instruments. The licensee's FIP states that control room instrumentation would be available due to the coping capability of the station batteries and associated inverters in Phase 1, or the portable DGs deployed in Phase 2. If no ac or dc power was available, the FIP states that key credited plant parameters, including these containment parameters, would be available using alternate methods.

The FIP identified key containment parameters as follows: suppression pool level, suppression pool water temperature, suppression chamber pressure, suppression chamber temperature, drywell pressure, and drywell temperature. With the exception of suppression pool water temperature, all instrumentation is channel A. Suppression pool water temperature is channel B.

Additional guidelines for alternately obtaining the critical parameters locally are provided in HC.OP-AM.TSC-0027, "Local Monitoring of Key Plant Parameters".

Based on this information, the licensee should have the ability to appropriately monitor the key containment parameters as delineated in NEI 12-06, Table 3-1.

3.4.4.2 Thermal-Hydraulic Analyses

The licensee completed analysis HC-MISC-005, "MAAP Analysis to Support FLEX Initial Strategy," as part of the basis of the HCGS FLEX mitigating strategies. The analysis used the MAAP, Version 4.0.6, to calculate the plant response to several scenarios. The analysis assumed a constant ambient temperature of 105 °F. The RCS total leakage is assumed to be 61 gpm, consisting of 18 gpm reactor recirculation pump seal leakage per pump and 25 gpm Technical Specification allowable leakage. The MAAP runs simulated 96 hours of operation following the loss of all ac power. There is a RCIC turbine backpressure trip at 50 psig on the steam exhaust line to the suppression pool. The licensee does not intend to block this RCIC trip. The licensee will open the HCVS vent line, which will reduce the pressure increase in the suppression pool, and also plans to eventually switch from RCIC to a FLEX pump for RPV injection.

For a seismically-induced ELAP (Case 1), the condensate storage tank is credited as a water source. The RCIC draws its suction from the CST until 30 minutes into the event. At roughly 30 minutes, operators will transfer the RCIC suction to the suppression pool to conserve CST inventory. The SRVs will reject reactor decay heat to the suppression pool. The decay heat will raise the suppression pool temperature. Roughly 4 hours into the event the suppression pool reaches 200 °F. At this time, the suppression pool will be vented to atmosphere using the HCVS, in order to vent steam and high temperature water vapor. When the suppression pool temperature approaches 215 °F, RCIC suction will be swapped back to the CST in order to use the cooler water in the CST. The RCIC will continue to be used until the CST is depleted at approximately 20 hours into the event, at which time the Phase 2 FLEX pump will replace the RCIC pump. Under this scenario, the maximum pressure for the wetwell is 35.5 pounds per square inch absolute (psia) (20.8 psig) and for the drywell is 35.3 psia (20.6 psig). The maximum drywell temperature is 289.6 °F and the maximum suppression chamber airspace temperature is 272.3 °F. The pressure remains below the design pressure of 62 psig. The drywell and suppression chamber temperatures remain below the design temperatures of 340 °F and 310 °F, respectively. The maximum values calculated are below the UFSAR design parameters stated above in Section 3.4, so the licensee has adequately demonstrated that there is significant margin before a limit would be reached and that the RCIC pump should not trip on high turbine backpressure.

3.4.4.3 FLEX Pumps and Water Supplies

As discussed in Section 2.5 of the HCGS FIP, permanently-installed plant equipment features are used to maintain containment integrity throughout the duration of the event; no non-permanently installed equipment (i.e., portable equipment) is directly required to maintain containment integrity. Makeup water to the suppression pool is initially through the RPV from water injected for core cooling. Later in the event, FLEX pumps can supply makeup water directly to the suppression pool. See Section 3.2.3.5, "FLEX Pumps and Water Supplies" for the evaluation of the portable pumps and the water supplies identified in the MAAP analyses.

3.4.4.4 Electrical Analyses

The licensee performed a containment evaluation based on the boundary conditions described in Section 2 of NEI 12-06. Based on the results of its evaluation, the licensee developed required actions to ensure maintenance of containment integrity and required instrumentation continues to function. With an ELAP initiated while Hope Creek is in Modes 1-4, containment cooling is also lost for an extended period of time. Therefore, containment temperature and pressure will slowly increase.

The licensee's Phase 1 coping strategy for containment involves verifying containment isolation per procedure HC.OP-AB.ZZ-0135(Q), and monitoring containment pressure and temperature using installed instrumentation. Control room indication for containment pressure and temperature is available for the duration of the ELAP/LUHS. The licensee's strategy to power instrumentation using the Class 1E station batteries is identical to the description in Section 3.2.3.6 of this SE and is adequate to ensure continued containment monitoring.

The licensee's Phase 2 coping strategy is to continue monitoring containment pressure and temperature using installed instrumentation. The licensee's strategy to repower instrumentation and the portable compressor (SRV operability) using a 480 Vac, 600 kW FLEX DG is identical to the description in Section 3.2.3.6 of this SE and is adequate to ensure continued containment monitoring and pressure control. Procedures HC.OP-EO.ZZ-0401(Q) and HC.OP-EO.ZZ-0407(Q) provide guidance for powering instrumentation and the portable compressor. The 480 Vac FLEX DGs will also power the HCVS.

The licensee's Phase 3 coping strategy is to reduce containment pressure and temperature utilizing existing plant systems restored by off-site equipment and resources during Phase 3. The licensee's strategy involves either venting containment or restoring the RHR system for indefinite containment cooling. The RHR system would be supplied power from the 4160 Vac CTGs supplied from an NSRC. Based on its review of licensee calculation E-15.16, the NRC staff determined that the electrical equipment supplied from an NSRC (e.g., 4160 Vac CTGs), has sufficient capacity and capability to supply the required loads to reduce containment pressure and temperature to ensure that key components and instrumentation remain functional.

Based on its review, the NRC staff finds that the licensee's electrical strategy is acceptable to restore or maintain containment indefinitely during an ELAP.

3.4.5 Conclusions

Based on this evaluation, the NRC staff concludes that the licensee has developed guidance that, if implemented appropriately, should maintain or restore containment functions following an ELAP event consistent with NEI 12-06 guidance, as endorsed by JLD-ISG-2012-01, and should adequately address the requirements of the order.

3.5 Characterization of External Hazards

Sections 4 through 9 of NEI 12-06 provide the methodology to identify and characterize the applicable BDBEEs for each site. In addition, NEI 12-06 provides a process to identify potential complicating factors for the protection and deployment of equipment needed for mitigation of applicable site-specific external hazards leading to an ELAP and loss of normal access to the UHS.

Characterization of the applicable hazards for a specific site includes the identification of realistic timelines for the hazard, characterization of the functional threats due to the hazard, development of a strategy for responding to events with warning, and development of a strategy for responding to events without warning.

The licensee reviewed the plant site against NEI 12-06 and determined that FLEX equipment should be protected from the following hazards: seismic; external flooding; severe storms with high winds; snow, ice and extreme cold; and extreme high temperatures.

References to external hazards within the licensee's mitigating strategies and this SE are consistent with the guidance in NEI-12-06 and the related NRC endorsement of NEI 12-06 in JLD-ISG-2012-01. NEI 12-06 directed licensees to proceed with evaluating external hazards based on currently available information. For most licensees, this meant that the OIP used the current design basis information for hazard evaluation. Coincident with the issuance of Order EA-12-049, on March 12, 2012, the NRC staff issued a Request for Information pursuant to Title 10 of the *Code of Federal Regulations* Part 50, Section 50.54(f) [Reference 19] (hereafter referred to as the 50.54(f) letter), which requested that licensees reevaluate the seismic and flooding hazards at their sites using updated hazard information and current regulatory guidance and methodologies. Due to the time needed to reevaluate the hazards, and for the NRC to review and approve them, the reevaluated hazards were generally not available until after the mitigation strategies had been developed. The NRC staff has developed a proposed rule, titled "Mitigation of Beyond-Design-Basis Events," hereafter called the MBDBE rule, which was published for comment in the *Federal Register* on November 13, 2015 [Reference 51]. The proposed MBDBE rule would make the intent of Orders EA-12-049 and EA-12-051 generically applicable to all present and future power reactor licensees, while also requiring that licensees consider the reevaluated hazard information developed in response to the 50.54(f) letter.

The NRC staff requested Commission guidance related to the relationship between the reevaluated flooding hazards provided in response to the 50.54(f) letter and the requirements for Order EA-12-049 and the MBDBE rulemaking (see COMSECY-14-0037, Integration of Mitigating Strategies for Beyond-Design-Basis External Events and the Reevaluation of Flooding Hazards" [Reference 45]. The Commission provided guidance in an SRM to COMSECY-14-0037 [Reference 20]. The Commission approved the staff's recommendations that licensees would need to address the reevaluated flooding hazards within their mitigating strategies for BDBEEs, and that licensees may need to address some specific flooding scenarios that could significantly impact the power plant site by developing scenario-specific mitigating strategies, possibly including unconventional measures, to prevent fuel damage in reactor cores or SFPs. The NRC staff did not request that the Commission consider making a requirement for mitigating strategies capable of addressing the reevaluated flooding hazards be immediately imposed, and the Commission did not require immediate imposition. In a letter to licensees dated September 1, 2015 [Reference 37], the NRC staff informed the licensees that the implementation of mitigation strategies should continue as described in licensee's OIPs, and that the NRC SEs and inspections related to Order EA-12-049 will rely on the guidance provided in JLD-ISG-2012-01, Revision 0, and the related industry guidance in NEI 12-06, Revision 0. The hazard reevaluations may also identify issues to be entered into the licensee's corrective action program consistent with the OIPs submitted in accordance with Order EA-12-049.

As discussed above, licensees are reevaluating the site seismic and flood hazards as requested in the NRC's 50.54(f) letter. After the NRC staff approves the reevaluated hazards, licensees will use this information to perform flood and seismic mitigating strategies assessments (MSAs) per the guidance in NEI 12-06, Revision 2, Appendices G and H [Reference 52]. The NRC staff endorsed Revision 2 of NEI 12-06 in JLD-ISG-2012-01, Revision 1 [Reference 53]. The licensee's MSAs will evaluate the mitigating strategies described in this SE using the revised seismic and flood hazards information and, if necessary, make changes to the strategies or equipment. Licensees will submit the MSAs for NRC staff review.

The licensee developed its OIP for mitigation strategies by considering the guidance in NEI 12-06 and the site's design-basis hazards. Therefore, this SE makes a determination based on the licensee's OIP and FIP. The characterization of the applicable external hazards for the plant site is discussed below.

3.5.1 Seismic

In its FIP, the licensee described the current design-basis seismic hazard, the SSE. As described in UFSAR Section 3.7.1.1, the SSE seismic criteria for the site is two-tenths of the acceleration due to gravity (0.20g) peak ground acceleration. It should be noted that the actual seismic hazard involves a spectral graph of the acceleration versus the frequency of the motion.

Peak acceleration in a certain frequency range, such as the numbers above, is often used as a shortened way to describe the hazard.

As the licensee's seismic reevaluation activities are completed, the licensee is expected to assess the mitigation strategies to ensure they can be implemented under the reevaluated hazard conditions as will potentially be required by the proposed MBDBE rulemaking. The licensee has appropriately screened in this external hazard and identified the hazard levels to be evaluated.

3.5.2 Flooding

In its FIP, the licensee described that the current design basis flooding mechanisms at HCGS are identified in UFSAR Table 2.4-6. Hope Creek has a nominal grade elevation of 101.5 feet PSD, which is equal to 12.5 feet above MSL. The maximum design still-water height is a result of the hurricane storm surge and is 113.8 feet PSD, which means there is 12.3 feet of water above grade level. The maximum run-up elevation at HCGS is 124.4 feet PSD for the power block structures and 134.4 feet PSD for the SWIS, as shown in UFSAR Tables 2.4-10 and 2.4-10a, respectively. In addition, the FIP described that the external flooding hazard was reevaluated. The reevaluation showed that the local intense precipitation (LIP) event is the only flooding hazard not bounded by the current design basis at HCGS. The reevaluated LIP event could produce flood levels that are above the watertight door thresholds, but significantly below the plant's minimum flood-protected elevation of 121 feet PSD; e.g., the maximum LIP flood level at critical door locations is 102.6 feet PSD. The licensee stated in its FIP that a hurricane storm surge event is assumed to have greater than 48 hours of warning time and flooding is expected to persist above site grade for approximately 11 hours. The licensee also described that HCGS does not rely on FLEX equipment for mitigation of ground water inleakage.

As the licensee's flooding reevaluation activities are completed, the licensee is expected to assess the mitigation strategies to ensure they can be implemented under the reevaluated hazard conditions as will potentially be required by the proposed MBDBE rulemaking. The licensee has appropriately screened in this external hazard and identified the hazard levels to be evaluated.

3.5.3 High Winds

In NEI 12-06, Section 7 provides the NRC-endorsed screening process for evaluation of high wind hazards. This screening process considers the hazard due to hurricanes and tornadoes. The screening for high wind hazards associated with hurricanes should be accomplished by comparing the site location to NEI 12-06, Figure 7-1 (Figure 3-1 of U.S. NRC, Technical Basis for Regulatory Guidance on Design Basis Hurricane Wind Speeds for Nuclear Power Plants, NUREG/CR-7005, December, 2009); if the resulting frequency of recurrence of hurricanes with wind speeds in excess of 130 miles per hour (mph) exceeds 1E-6 per year, the site should address hazards due to extreme high winds associated with hurricanes using the current licensing basis for hurricanes.

The screening for high wind hazard associated with tornadoes should be accomplished by comparing the site location to NEI 12-06, Figure 7-2, from U.S. NRC, Tornado Climatology of the Contiguous United States, NUREG/CR-4461, Rev. 2, February 2007; if the recommended tornado design wind speed for a 1E-6/year probability exceeds 130 mph, the site should address hazards due to extreme high winds associated with tornadoes using the current licensing basis for tornadoes or Regulatory Guide 1.76, Rev. 1.

In Section 2.6.4 of its FIP, the licensee identified that the site is located at 39° 27' 53" North latitude and 75° 32' 12" West longitude. Using Figures 7-1 and 7-2 from NEI 12-06, the reviewer determined that HCGS could experience hurricane winds of approximately 160 mph (Figure 7-1), and could experience tornado force winds of approximately 166 mph (Region 2 in Figure 7-2). Therefore, the plant screens in for an assessment for high winds from hurricanes and tornadoes, including missiles produced by these events.

In its FIP, the licensee described that per HCGS UFSAR Section 3.3, the design wind velocities are 108 mph at 30 feet above ground for Seismic Category I structures and 100 mph at 30 feet above ground for non-Seismic Category I structures. The design-basis tornado has a maximum wind speed of 360 mph, a maximum rotational speed of 290 mph with a radius of 150 feet, a maximum translational speed of 70 mph, and a minimum translational speed of 5 mph. Design-basis tornado missile characteristics are provided in UFSAR Table 3.5-12.

Therefore, high-wind hazards are applicable to the plant site. The licensee has appropriately screened in the high wind hazard and characterized the hazard in terms of wind velocities and wind-borne missiles.

3.5.4 Snow, Ice, and Extreme Cold

As discussed in NEI 12-06, Section 8.2.1, all sites should consider the temperature ranges and weather conditions for their site in storing and deploying FLEX equipment consistent with normal design practices. All sites outside of Southern California, Arizona, the Gulf Coast and Florida are expected to address deployment for conditions of snow, ice, and extreme cold. All sites located north of the 35th Parallel should provide the capability to address extreme snowfall with snow removal equipment. Finally, all sites except for those within Level 1 and 2 of the maximum ice storm severity map contained in Figure 8-2 should address the impact of ice storms.

In its FIP, regarding the determination of applicable extreme external hazards, the licensee stated that the site is located at 39° 27' 53" North latitude and 75° 32' 12" West longitude. In addition, the site is located within the region characterized by EPRI as ice severity level 3 (NEI 12-06, Figure 8-2, Maximum Ice Storm Severity Maps). Consequently, the site is subject to low to medium damage to power lines and/or existence of considerable amounts of ice. The licensee concludes that the plant screens in for an assessment for snow, ice, and extreme cold hazard. The FIP described that technical evaluation 80102074-0025, Outdoor Storage of FLEX Equipment in Extreme Cold and Hot Weather, established the minimum outdoor temperature of -4 °F. A review of UFSAR Section 2.3.2.1.2.1, "Temperatures," identified that the lowest hourly temperature recorded was -18.5 degrees Celsius, which is -1.3 °F.

In summary, based on the available local data and Figures 8-1 and 8-2 of NEI 12-06, the plant site does experience significant amounts of snow, ice, and extreme cold temperatures; therefore, the hazard is screened in. The licensee has appropriately screened in the hazard and characterized the hazard in terms of expected temperatures.

3.5.5 Extreme Heat

In the section of its FIP regarding the determination of applicable extreme external hazards, the licensee stated that, as per NEI 12-06 section 9.2, all sites are required to consider the impact of extreme high temperatures. Summer at the site may bring periods of extremely hot weather.

As described in the FIP, technical evaluation 80112074-0025 considered Salem and HCGS extreme temperature conditions for evaluation of outdoor FLEX equipment storage. Technical evaluation 80112074-0025 used a high temperature of 100 °F. A review of UFSAR Section 2.3.2.1.2.1 identified that the maximum hourly temperature recorded was 34.5 degrees Celsius, which is 94.1 °F. The plant site screens in for an assessment for extreme high temperature hazard.

In summary, based on the available local data and the guidance in Section 9 of NEI 12-06, the plant site does experience extreme high temperatures. The licensee has appropriately screened in the high temperature hazard and characterized the hazard in terms of expected temperatures.

3.5.6 Conclusions

Based on the evaluation above, the NRC staff concludes that the licensee has developed a characterization of external hazards that is consistent with NEI 12-06 guidance, as endorsed by JLD-ISG-2012-01, and should adequately address the requirements of the order in regard to the characterization of external hazards.

3.6 Planned Protection of FLEX Equipment

3.6.1 Protection from External Hazards

As described in the FIP, FLEX equipment required to mitigate a BDBEE at HCGS is stored at its point of deployment in a robust structure (e.g., new distribution equipment and pumps stored in the reactor and auxiliary buildings), or stored outside in locations separated by sufficient distance to minimize the probability that a single event would damage all FLEX mitigation equipment.

As described in the FIP, FLEX strategies include equipment pre-staged at their point of deployment, which is an alternative to portable Phase 2 equipment as suggested by NEI 12-06 and is discussed further in Section 3.14 of this SE.

Below are additional details on how FLEX equipment is protected from each of the applicable external hazards.

3.6.1.1 Seismic

In its FIP, the licensee described that FLEX equipment required to mitigate a seismic event at HCGS is stored at its point of deployment in a Seismic Category I structure (i.e., HCGS, Unit 1 reactor building, HCGS, Unit 1 auxiliary building and the HCGS, Unit 2 reactor building roof) or stored at locations evaluated to withstand the effects of a seismic event, including potential liquefaction. Large, portable FLEX equipment is secured for a seismic event or located so that it is not damaged by other items in a seismic event.

The FIP also described that FLEX equipment is stored adjacent to Seismic Category I buildings or away from areas where the equipment could be impacted by non-seismically robust components or structures. The required towing and debris removal equipment is located at Outdoor FLEX Storage Area 2 and will withstand a seismic event. The additional set of towing and debris removal equipment stored east of the HCGS cooling tower has not been evaluated for a seismic event and is not credited.

In its FIP, the licensee described that installed FLEX equipment credited following a seismic event is seismically robust, consistent with HCGS's current seismic design practices. Installed FLEX equipment is protected from seismic interactions based on its location within the auxiliary or reactor buildings to ensure that unsecured or non-seismic components do not damage the equipment. In addition, the FIP described that the FLEX equipment stored in HCGS, Unit 2 addressed the seismic protection criteria of NEI 12-06 Section 5.3.1, based on an evaluation performed by the licensee.

3.6.1.2 Flooding

In its FIP, the licensee described that two FLEX DGs are pre-staged on the HCGS, Unit 2 reactor building roof. This elevation is above the LIP and hurricane storm surge flood depths and is not vulnerable to any other external flooding events. Procedures have been revised to close watertight doors if a LIP is forecasted. A hurricane storm surge event is assumed to have greater than 48 hours of warning time and flooding is expected to persist above site grade for approximately 11 hours.

The FIP also described that the FLEX equipment required to mitigate a flooding event at HCGS is stored at its point of deployment in a flood-protected structure (i.e., HCGS, Unit 1 reactor building), above the flood elevation (i.e., HCGS, Unit 2 reactor building roof) or will be stored in the flood-protected HCGS, Unit 2 reactor building. In addition, the diesel-driven FLEX service water pumps, including the N+1 pump, will be moved to the flood-protected HCGS, Unit 2 reactor building from the normal outdoor storage locations within the protected area before the arrival of a hurricane and deployed after flood waters recede.

The FIP described that the debris removal equipment will be moved to the flood-protected HCGS, Unit 1 reactor building prior to the hurricane to support deployment of FLEX equipment in Phases 2 and 3. In addition, towing equipment will be staged in the flood-protected HCGS, Unit 2 reactor building prior to the hurricane to support deployment of FLEX equipment in Phases 2 and 3.

In its FIP, the licensee described that procedure OP-AA-108-111-1001, Severe Weather and Natural Disaster Guidelines, provides guidance for severe weather warnings, and triggers protective measures including closure of watertight doors and protection of FLEX equipment. FLEX equipment flood protection actions are performed in accordance with SH.OP-AM.FLX-0050, "Pre-Storm Storage and Protection of Outdoor FLEX Equipment."

3.6.1.3 High Winds

As described in the FIP, FLEX equipment required to mitigate a BDBEE at HCGS is stored at its point of deployment in a robust structure (e.g., new distribution equipment and pumps stored in the reactor and auxiliary buildings), or stored in locations separated by sufficient distance to minimize the probability that a single event would damage all FLEX mitigation equipment. The primary FLEX equipment stored outdoors includes the diesel-driven FLEX pumps and FLEX DGs. This equipment will not be missile protected, but is separated by a significant distance to ensure a single event does not damage all FLEX mitigating equipment such that at least N sets of FLEX equipment would remain deployable in accordance with NEI 12-06, Section 7.3.1(c). Therefore, at least one FLEX DG and two diesel-driven FLEX pumps will be available for deployment following a tornado event. A minimum separation distance of 1,200 feet for tornado missile protection of outdoor FLEX equipment is supported by the licensee's site-specific evaluation of tornado characteristics documented in evaluation VTD 903078, "FLEX Water Storage Tornado Wind Hazard Evaluation." Evaluation VTD 903078 was performed for the Salem Nuclear Generating Station but the same tornado characteristics apply to the HCGS since they are both located on the same site. There are three outdoor FLEX storage areas (OFSA1, OFSA2, and OFSA3) at the site. They are aligned mostly along a north-south axis, with OFSA1 to the south, OFSA3 to the north, and OFSA2 in between. As shown in design change package DCP80112074, "Outdoor FLEX Storage Areas," Revision 2, there is about 1618 feet of separation from OFSA1 to OFSA2, and about 1337 feet of separation from OFSA2 to OFSA3. VTD 903078 shows that most tornadoes in this locale are expected to come from the southwest (including west, west-southwest, and south-southwest) and move eastward across the site. Based on the licensee's analysis of tornado size and travel paths, the NRC staff concluded that it is very unlikely that a single tornado would damage more than one outdoor storage location.

In its FIP, the licensee described that the two FLEX DGs stored at the deployment location on the HCGS, Unit 2 reactor building roof are not missile protected. However, these FLEX DGs are located in an area where protective actions will be taken to reduce the potential for wind impacts. The location on the HCGS, Unit 2 reactor building roof is considered a protected location since it is elevated 30 feet above grade and protected to the south and east by much taller buildings. Section 3.1 of NUREG/CR-7004, "Technical Basis for Regulatory Guidance on Design-Basis Hurricane-Borne Missile Speeds for Nuclear Power Plants," notes that, unlike tornadoes, forces that increase the elevation of a hurricane missile with respect to ground are negligible. A footnote to this section discusses automobile missiles and concludes that automobiles may be rolled around at ground level during a hurricane, but will not go airborne. Therefore, hurricane wind missiles in general will be lower to the ground and unlikely to be elevated to over 30 feet above grade.

In addition, the licensee described in its FIP that the two pre-staged FLEX DGs are reasonably protected to provide N and N+1 capability during BDBEE scenarios other than a tornado missile event. For a tornado missile event affecting both FLEX DGs, the licensee would deploy a spare FLEX DG from an outdoor storage area sufficiently separated from the Unit 2 reactor building to support the FLEX strategy in the event that both FLEX DGs on the roof are damaged. FLEX timelines and staffing resources account for the time to deploy the spare DG in a tornado missile scenario if needed. The HCGS FLEX DG storage and deployment strategy considers the external hazards applicable to the site and provides reasonable assurance that no single event will defeat the FLEX strategy.

In its FIP, the licensee described that the HCVS piping and components located less than 30 feet above grade are protected from all missiles by the walls of the reactor building. The reactor building is a Seismic Category I structure and is designed to provide protection from the design-basis tornado wind and missiles. Technical evaluation 80115583-0860 documents the basis for reasonable protection of the HCVS piping external to the reactor building from wind-borne missile hazards.

3.6.1.4 Snow, Ice, Extreme Cold and Extreme Heat

In its FIP, the licensee described that the HCGS plan for storage locations includes either storage inside robust structures, storage on the roof of the Hope Creek, Unit 2 reactor building, or storage at three outside locations (without storage buildings) with enough separation so that only one outside storage area would be impacted by a tornado. The licensee established the minimum outdoor temperature as -4 °F and the highest outdoor temperature as 100 °F.

The FIP described that HCGS is using an alternative to the criteria of NEI 12-06, Section 8.3.1, "Protection of FLEX Equipment," which recommends storage of the N FLEX equipment within a structure to provide protection against snow, ice and extreme cold hazards. The licensee stated that equipment stored outdoors is designed for outdoor storage in cold environments consistent with normal design practices, e.g., using diesel engine block heaters and space heaters. In addition, the FIP described that the licensee integrated the FLEX capabilities into existing site cold weather procedures and established periodic FLEX equipment status checks that include diesel keep-warm systems and verification that access to equipment is not impaired by snow or ice. The NRC staff finds this to be an acceptable alternative, as the licensee has taken steps to ensure that the FLEX equipment will be functional if it is needed. For further discussion on this, refer to Section 3.14 below.

In its FIP, the licensee described that all FLEX equipment has been procured to be suitable for use at the peak temperature. Therefore, high temperature does not impact the functionality of FLEX equipment.

3.6.1.5 Conclusions

Based on this evaluation, the NRC staff concludes that the licensee has developed guidance that, if implemented appropriately, should protect the FLEX equipment during a BDBEE consistent with NEI 12-06 guidance, as endorsed by JLD-ISG-2012-01, with approved alternatives, and should adequately address the requirements of the order.

3.6.2 Availability of FLEX Equipment

Section 3.2.2 of NEI 12-06 states, in part, that in order to assure reliability and availability of the FLEX equipment, the site should have sufficient equipment to address all functions at all units on-site, plus one additional spare (i.e., an N+1 capability, where "N" is the number of units on site). It is also acceptable to have a single resource that is sized to support the required functions for multiple units at a site (e.g., a single pump capable of all water supply functions for a dual unit site). In this case, the N+1 could simply involve a second pump of equivalent capability. In addition, it is also acceptable to have multiple strategies to accomplish a function, in which case the equipment associated with each strategy does not require an additional spare. Table 1 in the FIP, "FLEX Equipment Stored On-Site," provides a listing of FLEX equipment stored on-site.

In its FIP, the licensee described that they have purchased sufficient equipment to address all functions at all three units on-site, plus one additional spare, i.e., an N+1 capability, where "N" is the number of equipment required by FLEX strategies for all three units on-site. Salem, Units 1 and 2, and HCGS, Unit 1 and the partially constructed HCGS, Unit 2 are co-located on a common site (i.e., the units are in a common protected area, use a common emergency plan, security plan, etc.). For major FLEX equipment common to all units (FLEX DGs and diesel-driven FLEX SW pumps), the N+1 requirement is met by providing at least one spare, in addition to the minimum set of equipment needed for all three operating reactors.

In addition, the FIP described that for the hoses and cables associated with FLEX equipment required for FLEX strategies, the licensee is using the NRC-endorsed alternative to NEI 12-06, Section 3.2.2, rather than have a complete extra set of hoses and cables. The basic premise of the alternative is that an extra 10 percent of hoses and cables would be sufficient, with certain qualifiers. This alternative is more fully explained in Section 3.14 below.

Based on the number of portable FLEX pumps, FLEX DGs, and support equipment identified in the FIP and during the audit review, the NRC staff finds that, if implemented appropriately, the licensee's FLEX strategies include a sufficient number of portable FLEX pumps, FLEX DGs, and equipment for RPV makeup, SFP makeup, and maintaining containment consistent with the N+1 recommendation in Section 3.2.2 of NEI 12-06, with an approved alternative for spare hoses and cables.

3.7 Planned Deployment of FLEX Equipment

In its FIP, the licensee described that pre-determined, preferred haul paths have been identified and documented in the FSGs. Figure 3 of the FIP provides guidance related to the haul paths from the storage locations to the various deployment locations. Deployment pathways for FLEX equipment were selected to avoid the potential for debris from failed, non-seismically designed structures. Debris removal equipment onsite will be capable of clearing pathways for deployment.

The FIP described that Phase 3 of the FLEX strategies involves the receipt of equipment from offsite sources including an NSRC and the receipt of various commodities such as fuel and supplies. Delivery of this equipment can be through airlift (helicopter) or via ground transportation. Debris removal from the pathway between the site and the NSRC receiving locations (staging areas) and from the various plant access routes may be required. The same debris removal equipment used for onsite pathways may also be used to support debris removal to facilitate road access to the site once necessary haul routes and transport pathways onsite are clear.

3.7.1 Means of Deployment

In its FIP, the licensee described that towing and debris removal equipment are stored so that one set of equipment (one towing vehicle, one debris removal vehicle, and one forklift) will survive all hazards. Onsite debris removal equipment is available to clear pathways. In addition, snow removal is a normal activity at the plant site because of the climate. Reasonable access to FLEX equipment will be maintained throughout a snow event in accordance with plant procedure MA-AA-716-002-1002, "Facilities Maintenance Guidelines." Ice management will be performed as required such that large FLEX equipment can be moved by vehicles. Debris removal equipment can move through moderate snow accumulation and can also be used to move FLEX equipment.

3.7.2 Deployment Strategies

During a high wind event, the FIP described that there may be a delay in the deployment of FLEX equipment. Consequently, the FLEX strategy includes consideration for deployment of equipment prior to the high wind event, since significant warning time would typically be available. It is noted that for tornadoes there may not be significant warning time available. Since tornadoes are typically short-term events, deployment of equipment during a tornado would not be needed. In its FIP, the licensee described that towing and debris removal equipment is diversely located, separated by a significant distance to ensure a single tornado does not impact more than one set of towing and debris removal equipment, and therefore available to support deployment of FLEX equipment.

In its FIP, the licensee described that procedure SH.OP-AM.FLX-0051, "Salem/Hope Creek Shared FLEX Equipment Phase 2 Deployment," includes instructions for deploying FLEX equipment, debris removal, and towing vehicles after hurricane flood waters recede.

As described in the HCGS UFSAR, Section 2.5.4.8.3, non-liquefiable backfill surrounds the top 30 feet of power block and intake structures up to final grade.

In its FIP, the licensee described that the potential effect of frazil ice was addressed by having more than one strainer assembly for each diesel-driven FLEX pump. If there is a clogging issue from ice or debris, the strainer can be pulled from the river and exchanged and cleaned as necessary. If surface ice on the river prevents normal access for the FLEX diesel-driven service water pump, the pump suction hose would be routed to inside the icebreakers in front of the SWIS.

3.7.3 Connection Points

3.7.3.1 Mechanical Connection Points

Core Cooling

In the FIP, Sections 2.3.5.1 and 2.3.5.2 describe the primary and alternate connection points used by the FLEX alternate header pump to inject water into the RPV. In addition, FIP Figure 1 shows the connection points and flow paths from the pump to the RPV. The primary FLEX connection point is at the "B" SW to emergency RHR crosstie. This connection point is in the

RACS pump area room in the reactor building. The alternate FLEX connection point is at the "A" RHR heat exchanger in the "A" RHR heat exchanger room in the reactor building. The reactor building is a Seismic Category I structure and protects the connection points from all external hazards.

In the FIP, Section 2.3.2 describes the FLEX connection points used by the diesel-driven FLEX pump to inject river water into the RPV. The diesel-driven FLEX pump will be deployed near the SWIS and a suction hose with strainer will be placed in the river. Another hose will be run from the pump discharge to a FLEX connection on the "A" or "B" SW header located inside the SWIS. In the FIP, Section 2.3.2 states that the SWIS is a hardened structure. As described in Table 3.2-1 of the UFSAR, the SWIS is a Seismic Category I structure and protects the equipment inside from external hazards. The diesel-driven FLEX pump will pressurize the SW piping into the reactor building and a flow path will be established from the SW piping to the RHR piping and then into the RPV. In the FIP, Figure 1 shows the connection points and flow paths from the pump to the RPV. Components along this path from the SW piping in the reactor building to the RPV are protected from external hazards by the reactor building.

SFP Cooling

In the FIP, Sections 2.4.5.1 and 2.4.5.2 describe primary and alternate connection points used by the diesel-driven FLEX pump to supply river water to the SFP. As described for core cooling, the diesel-driven FLEX pump connects to the "A" or "B" SW header in the SWIS. The "B" SW header is the primary connection point and the "A" SW header is the alternate connection point. In the FIP, Section 2.4.2 describes the flow path from the SW piping to the SFP. Water is supplied using the existing fill path in the SW system or using an emergency fill line in the RACS pump area room at the 77 ft elevation. In the FIP, Section 2.4.2 states that the emergency fill line flow path is the same one used for RPV injection, but flow is diverted to the SFP through installed piping (also shown on FIP Figure 1).

In the FIP, Section 2.4.2 describes connection points used by the FLEX alternate header pump to supply water from the CST (if available) or suppression pool. Water can be routed from the pump to a FLEX standpipe and then to a hose staged on the refueling floor or to the existing B.5.b spray nozzle. Alternatively, water can be supplied through the FLEX injection header to the SW emergency fill line in the RACS pump area room at the 77 ft elevation.

In the FIP, Figure 1 shows the connection points and flow paths to the SFP from the diesel-driven FLEX pump and FLEX alternate header pump. As described in FIP Section 2.4.5, the connections and valves to fill the SFP from the SW piping in the reactor building or the FLEX alternate header pump are protected from all external hazards by the reactor building.

Given the design and location of the primary and alternate connection points, as described in the above paragraphs, the staff finds that at least one of the connection points should be available to support core and SFP cooling during an ELAP caused by an external event, consistent with NEI 12-06 Section 3.2.2.

3.7.3.2 Electrical Connection Points

Electrical connection points are only applicable for Phases 2 and 3 of the licensee's mitigation strategies for a BDBEE that results in an ELAP.

For Phase 2, the licensee has developed a primary and alternate electrical connection strategy for supplying power to equipment required to maintain or restore core cooling, containment, and SFP cooling using a combination of permanently installed and portable components. The licensee's primary connection strategy is to use the two permanently installed 600 kW FLEX DGs located on the Unit 2 reactor building roof to power unit substations 10B410 (A) and 10B420 (B). The FLEX DG would be connected to the FLEX MCC located on the 130' elevation of the Unit 2 auxiliary building Control/Diesel Area via portable FLEX and permanent cables. The FLEX MCC is connected to FLEX receptacles near the "A" and "B" unit substations in the Unit 1 switchgear rooms via permanent cables. Back-feed breakers are installed in the unit substations and wired to FLEX receptacles. The FLEX receptacles would be connected to the unit substation back-feed breaker receptacles via FLEX cables to make the final connections. There is also a permanent cable that is routed from the FLEX MCC to a FLEX receptacle in the "B" core spray room of the reactor building to power the FLEX alternate header pump.

The licensee's alternate connection strategy uses the permanently installed 600 kW FLEX DGs to power the FLEX MCC as stated in the primary strategy. The FLEX MCC is connected to receptacles near the 250 Vdc and 125 Vdc battery chargers via permanent cables. The FLEX receptacles would be connected to the battery charger receptacles via FLEX cables to make the final connections. There is also a second receptacle that is connected via permanent cable from a breaker in the 10B222 MCC to provide an alternate feed for the FLEX alternate header pump.

If both FLEX DGs on the Unit 2 reactor building roof were damaged by a tornado, the portable 600 kW FLEX DG would be used instead. The licensee would deploy the FLEX DG outside the Unit 1 auxiliary building diesel truck bay door. The FLEX DG would be connected to the FLEX MCC via FLEX cables. Procedure HC.OP-EO.ZZ-0401(Q) provides direction for connecting the permanent and portable 600 kW FLEX DGs. In its FIP, the licensee stated that the correct phase rotation of the Phase 2 FLEX DGs was verified during modification acceptance testing.

For Phase 3, the licensee will receive four 1 MW 4160 Vac CTGs and one 1000 kW 480 Vac CTG from an NSRC. The NSRC supplied 4160 Vac CTGs would be deployed to the west side of the auxiliary building control/diesel area near the EDG truck bay door. Power would be restored to 4160 Vac Class 1E switchgear 10A401. Procedure HC.OP-EO.ZZ-0402 (Q), "FLEX Electrical – Phase 3," Revision 1, provides direction for staging, connecting, and loading the 4160 Vac CTGs. Design change DCP 80112547, "Hope Creek FLEX Electrical Modification – Phase 3," Revision 3, provides direction to verify proper phase rotation.

3.7.4 Accessibility and Lighting

In its FIP, the licensee described that the potential impairments to required access are: 1) doors and gates, and 2) debris blocking personnel or equipment access. The coping strategy to maintain site accessibility through doors and gates is applicable to all phases of the FLEX coping strategies, but is essential as part of the immediate activities required during Phase 1.

The FIP described that doors and gates serve a variety of barrier functions on the site. One primary function, security, is discussed below. Other barrier functions include fire, flood, radiation, ventilation, tornado, and protection from high energy pipe breaks. These doors and gates are typically administratively controlled to maintain their function as barriers during normal operations. Following a BDBEE and subsequent ELAP event, FLEX coping strategies require the routing of hoses and cables through various barriers in order to connect portable FLEX equipment to station fluid and electric systems. For this reason, certain barriers (gates and doors) will be opened and remain open. This deviation from normal administrative controls is acknowledged and is acceptable during the implementation of FLEX coping strategies. The watertight doors required for flood protection during a flooding event have pneumatic seals that do not require power to operate.

The FIP also described that the ability to open doors for ingress and egress, ventilation, or temporary cables/hoses routing is necessary to implement the FLEX coping strategies. During an ELAP, personnel and vehicle access to the Protected Area is controlled by the Security Plan and implementing procedures that include provisions for alternate means of access control. Internal locked areas are also subject to Security control during an ELAP and access will be controlled in accordance with administrative controls.

As described in the FIP, lighting is required for operator actions and access in the plant to implement actions associated with the SBO procedure. Emergency lighting is provided by local battery-powered emergency lighting. The availability of this lighting is at least 8 hours. The main control room (MCR) emergency lighting will be available for 8 hours from internal batteries (Appendix R lighting).

In addition, the FIP described that portable battery powered lights will also be available for use in areas that require operator access to perform Phase 2 equipment connections.

3.7.5 Access to Protected and Vital Areas

During the audit process, the licensee provided information describing that access to protected areas will not be hindered. The licensee has contingencies in place to provide access to areas required for the ELAP response if the normal access control systems are without power.

3.7.6 Fueling of FLEX Equipment

In its FIP, the licensee described that the portable equipment used in Phase 2 is equipped with fuel storage tanks sufficient for at least 12 hours of operation without refueling to minimize actions required to keep equipment running. The existing EDG fuel oil pumps will be repowered via the unit substations. Fuel oil will be pumped to the EDG day tanks, where a portable FLEX hose can be connected to a day tank drain valve. That hose will be connected to a FLEX fuel oil transfer pump, powered by the FLEX MCC. For the FLEX DGs on the roof, fuel oil will be pumped via installed piping to a connection on elevation 136', near the door that leads to the FLEX DGs on the roof. A fill hose is staged near the door for filling the FLEX DGs. The FLEX fuel oil transfer pump will also be used to fill portable fuel transfer tanks (Transcubes) at ground level, that will be used to supply remote diesel-driven equipment (e.g. debris removal equipment, diesel-driven FLEX pumps, etc).

As described in technical evaluation 80113610-0070, "Evaluation of FLEX Portable Equipment Fuel Usage Against NEI 12-06 Requirements for Hope Creek," HCGS has four EDG day tanks that contain a minimum of 360 gallons of fuel each and eight fuel oil storage tanks (two for each EDG) with each EDG's tanks containing a minimum of 44,800 gallons. The EDG day tanks and EDG fuel oil tanks are safety related and located within the Hope Creek auxiliary building; therefore, they are protected against all hazards. Between the four EDG day tanks and the eight EDG fuel oil storage tanks, there is a minimum of 180,640 gallons of fuel oil at HCGS that would be available after a BDBEE.

The technical evaluation defined the fuel usage for the FLEX equipment assuming full load values from information supplied by the equipment vendor or estimated using similar equipment. In order to determine the maximum potential fuel usage, all Phase 2 equipment was assumed to run at full load from the time it would be placed in service and then operated indefinitely during the BDBEE. With these assumptions, the estimated hourly fuel usage for all Phase 2 FLEX equipment is 75.85 gallons per hour (gph). The total estimated fuel consumption for the first 24 hours is about 1,263 gallons. With a minimum of 180,640 gallons of fuel oil, the Phase 2 FLEX equipment, operating at full load, would run for over 99 days. When Phase 3 equipment is included in the evaluation, fuel oil consumption increases to about 655 gph. This increased fuel oil usage rate would result in 11.4 days of fuel oil supply. Fuel oil would then be supplied from offsite.

The technical evaluation also described that the testing for fuel contained in the portable equipment will be added to the preventive maintenance program for that equipment. The licensee described that the EDG fuel oil is subject to testing in accordance with surveillance requirements in HCGS Technical Specification 4.8.1.1.2. In addition, the licensee described that fuel levels in FLEX equipment is monitored and refilled as needed in accordance with their surveillance program.

3.7.7 Conclusions

Based on this evaluation, the NRC staff concludes that the licensee has developed guidance that, if implemented appropriately, should allow deploying the FLEX equipment following a BDBEE consistent with NEI 12-06 guidance, as endorsed by JLD-ISG-2012-01, and should adequately address the requirements of the order.

3.8 Considerations in Using Offsite Resources

3.8.1 Hope Creek SAFER Plan

The industry has collectively established the needed off-site capabilities to support FLEX Phase 3 equipment needs via the SAFER team. The SAFER team consists of the Pooled Equipment Inventory Company (PEICo) and AREVA Inc. and provides FLEX Phase 3 management and deployment plans through contractual agreements with every commercial nuclear operating company in the United States.

There are two NSRCs, located near Memphis, Tennessee and Phoenix, Arizona, established to support nuclear power plants in the event of a BDBEE. Each NSRC holds five sets of equipment, four of which will be able to be fully deployed to the plant when requested. The fifth set allows removal of equipment from availability to conduct maintenance cycles. In addition, the plant's FLEX equipment hose and cable end fittings are standardized with the equipment supplied from the NSRC.

By letter dated September 26, 2014 [Reference 23], the NRC staff issued its assessment of the NSRCs established in response to Order EA-12-049. In its assessment, the staff concluded that SAFER has procured equipment, implemented appropriate processes to maintain the equipment, and developed plans to deliver the equipment needed to support site responses to BDBEEs, consistent with NEI 12-06 guidance; therefore, the staff concluded in its assessment that licensees can reference the SAFER program and implement their SAFER Response Plans to meet the Phase 3 requirements of Order EA-12-049.

The NRC staff noted that the licensee's SAFER Response Plan contains (1) SAFER control center procedures, (2) NSRC procedures, (3) logistics and transportation procedures, (4) staging area procedures, which include travel routes between staging areas to the site, (5) guidance for site interface procedure development, and (6) a listing of site-specific equipment (generic and non-generic) to be deployed for FLEX Phase 3.

3.8.2 Staging Areas

In general, up to four staging areas for NSRC-supplied Phase 3 equipment are identified in the SAFER Plans for each reactor site. These are a Primary (Area C) and an Alternate (Area D), if available, which are offsite areas (within about 25 miles of the plant) utilized for receipt of ground transported or airlifted equipment from the NSRCs. From Staging Areas C and/or D, the SAFER team will transport the Phase 3 equipment to the on-site Staging Area B for interim staging prior to it being transported to the final location in the plant (Staging Area A) for use in Phase 3. For HCGS, Alternate Staging Area D is Atlantic City International Airport. Staging Area C is the Millville Municipal Airport. Staging Area B is the end of Buttonwood Road in Hancocks Bridge, New Jersey (a large laydown area north of the Learning and Development Center and east of the Hope Creek cooling tower). Staging Area A is the point-of-use for the FLEX response equipment.

Use of helicopters to transport equipment from Staging Area C to Staging Area B is recognized as a potential need within the HCGS SAFER Plan and is provided for.

3.8.3 Conclusions

Based on this evaluation, the NRC staff concludes that the licensee has developed guidance that, if implemented appropriately, should allow utilization of offsite resources following a BDBEE consistent with NEI 12-06 guidance, as endorsed by JLD-ISG-2012-01, and should adequately address the requirements of the order.

3.9 Habitability and Operations

3.9.1 Equipment Operating Conditions

3.9.1.1 Loss of Ventilation and Cooling

Following a BDBEE and subsequent ELAP event at Hope Creek, ventilation that provides cooling to occupied areas and areas containing required equipment will be lost. The primary concern with regard to ventilation is the heat buildup which occurs with the loss of forced ventilation in areas that continue to have heat loads. The licensee performed a loss of ventilation analysis to quantify the maximum steady-state temperatures expected in specific areas related to their FLEX mitigation strategy implementation to ensure that the environmental conditions remain acceptable and within equipment qualification limits. The key areas identified for all phases of execution of the licensee's FLEX strategy activities are the MCR, 250 Vdc HPCI/RCIC Battery and Battery Charger Rooms, Relay Room, Inverter Room, Switchgear Room, 125 Vdc Battery Rooms, RCIC Pump Room, and Containment.

Main Control Room (including the Electrical Access Area)

Licensee analysis Vendor Technical Document (VTD) 432340, "Hope Creek Auxiliary Building Extended Loss of AC Power FLEX Response," Revision 3, modeled the transient temperature response in the MCR following an ELAP event. The analysis showed that the MCR will be maintained below 102 °F with the use of a 3700 cubic feet per minute (cfm) portable fan placed in the Shift Managers office and discharge to the MCR. Procedure HC.OP-AB.ZZ-0135(Q) provides guidance to monitor and establish portable ventilation if MCR temperature exceeds 90 °F. The procedure also provides guidance to block open doors and remove ceiling tiles within 30 minutes of an ELAP event.

Based on expected room temperature remaining below 120 °F (the temperature limit, as identified in NUMARC-87-00, "Guidelines and Technical Bases for NUMARC Initiatives Addressing Station Blackout at Light Water Reactors," Revision 1, for electronic equipment to be able to survive indefinitely), the NRC staff finds that the electrical equipment in the MCR will not be adversely impacted by the loss of ventilation as a result of an ELAP event.

Class 1E HPCI / RCIC (250 Vdc) Battery Rooms and Battery Charger Rooms 54' Elevation

Licensee analysis H-1-FLX-MDC-1046 modeled the transient temperature response in the HPCI and RCIC battery and battery charger rooms following an ELAP event. The analysis showed that the HPCI and RCIC battery room temperatures at 72 hours would be 76 °F and 72 °F, respectively. The analysis showed that the HPCI and RCIC battery charger room temperatures at 72 hours would be 84 °F and 88 °F, respectively. Procedure HC.OP-AB.ZZ-0401(Q) provides guidance to open doors to facilitate room cooling.

Based on the HPCI and RCIC battery charger room temperatures remaining below 120 °F (the temperature limit, as identified in NUMARC-87-00), the NRC staff finds that the electrical equipment in the HPCI and RCIC battery charger rooms will not be adversely impacted by the loss of ventilation as a result of an ELAP event.

Based on the above, the NRC staff finds that the licensee's ventilation strategy (open doors and restore ventilation) should maintain battery room temperature below the maximum temperature limit (122 °F) of the batteries, as specified by the battery manufacturer (C&D Technologies). Therefore, the batteries should not be adversely impacted by the loss of ventilation as a result of an ELAP event. While the battery vendor's analysis shows that the batteries are capable of performing their function up to 122 °F, periodic monitoring of electrolyte level may be necessary to protect the battery since the battery may gas more at higher temperatures.

Lower Control Equipment Room (Relay Room) 102' Elevation

Licensee analysis VTD 432340 modeled the transient temperature response in the relay room following an ELAP event. The analysis showed that the relay room temperature at 72 hours begins to stabilize at around 104 °F. Procedure HC.OP-AB.ZZ-0135(Q) provides guidance to open doors to facilitate room cooling. This action should be completed early (within 30 minutes) in an ELAP event.

Based on expected relay room temperatures remaining below 120 °F (the temperature limit, as identified in NUMARC-87-00), the NRC staff finds that the electrical equipment in the relay room will not be adversely impacted by the loss of ventilation as a result of an ELAP event.

Class 1E Inverter Rooms 124' Elevation

Licensee analysis VTD 432340 modeled the transient temperature response in the Class 1E inverter rooms (5447 and 5448) following an ELAP event. The analysis showed that the inverter room temperatures (5447 and 5448) at 72 hours would be 86 °F and 94 °F, respectively. Procedure HC.OP-AB.ZZ-0135(Q) provides guidance to open doors to facilitate room cooling. This action should be completed early (within I hour) in an ELAP event.

Based on expected inverter room temperatures remaining below 120 °F (the temperature limit, as identified in NUMARC-87-00), the NRC staff finds that the electrical equipment in the Class 1E inverter room will not be adversely impacted by the loss of ventilation as a result of an ELAP event.

Class 1E Switchgear Rooms 130' Elevation

Licensee analysis VTD 432340 modeled the transient temperature response in the Class 1E switchgear rooms (5413 and 5417) following an ELAP event. The analysis showed that the cyclic peak switchgear room temperatures at 72 hours are 110 °F and 116 °F, respectively. Procedure HC.OP-AB.ZZ-0401(Q) , provides guidance to open doors to facilitate room cooling. This action should be completed early (within I hour) in an ELAP event.

Based on expected switchgear room temperatures remaining below 120 °F (the temperature limit, as identified in NUMARC-87-00), the NRC staff finds that the electrical equipment in the Class 1E switchgear rooms will not be adversely impacted by the loss of ventilation as a result of an ELAP event.

Class 1E (125 Vdc) Battery Rooms and Battery Charger Rooms 146' Elevation

Licensee analysis VTD 432340 modeled the transient temperature response in the Class 1E battery rooms and battery charger rooms following an ELAP event. The analysis showed that the Class 1E battery room temperature for batteries 1AD411, 1BD411, 1CD411, and 1DD411 at 72 hours are 100 °F, 96 °F, 94 °F and 94 °F, respectively. The analysis showed that the Class

1E battery charger room temperature for the above batteries are 113 °F, 112 °F, 93 °F and 94 °F, respectively. Procedure HC.OP-AB.ZZ-0401(Q) provides guidance to open doors to facilitate room cooling.

Based on expected Class 1E battery charger room temperatures remaining below 120 °F (the temperature limit, as identified in NUMARC-87-00), the NRC staff finds that the electrical equipment in the Class 1E battery charger rooms will not be adversely impacted by the loss of ventilation as a result of an ELAP event.

Based on the above, the NRC staff finds that the licensee's ventilation strategy (open doors and restore ventilation) should maintain battery room temperature below the maximum temperature limit (122 °F) of the batteries, as specified by the battery manufacturer (C&D Technologies). Therefore, the batteries should not be adversely impacted by the loss of ventilation as a result of an ELAP event. While the battery vendor's analysis shows that the batteries are capable of performing their function up to 122 °F, periodic monitoring of electrolyte level may be necessary to protect the battery since the battery may gas more at higher temperatures.

Reactor Core Isolation Cooling Room

To ensure RCIC continues to provide injection flow to the RPV, the equipment area high temperature system isolations are defeated (or bypassed) per procedure HC.OP-AB.ZZ-0135, as described in FIP Sections 2.3.1 and 2.11.1.

B Core Spray Pump Room

The two FLEX alternate header pumps are located in the B Core Spray Pump Room (Room 4104) of the reactor building. The licensee states in Technical Evaluation 80113610-0200 that temperature rises in this room to 109 °F at 72 hours. Because the pumps are qualified to an ambient air temperature of 115 °F, no additional compensatory actions are required for equipment operability.

Drywell Access Area

The FLEX air compressor is located in the drywell access area (Room 4331) of the reactor building. The licensee states in Technical Evaluation 80113610-0200 that this room reaches a maximum temperature of 102.7 °F. Because the FLEX air compressor is qualified to an ambient air temperature of 104 °F (per vendor manual VTD 432627), no additional compensatory actions are required for equipment operability.

Containment

Licensee calculation HC-MISC-005, "MAAP Analysis to Support FLEX Initial Strategy," Revision 7, modeled the transient temperature response in the containment following the first 96 hours of an ELAP event. This calculation included containment environmental conditions that would be expected during an ELAP event. The calculation identified a 340 °F and 62 psig acceptance criteria for the drywell. The results of the licensee's analysis indicated that the maximum temperature in the drywell would be approximately 289.6 °F during an ELAP event. The analysis of also showed that the environmental qualification (EQ) of critical drywell components (i.e., safety/relief valve (SRV) solenoids, drywell seals, penetrations, and Regulatory Guide 1.97 instrumentation for reactor level, reactor pressure, drywell pressure, and drywell temperature) envelops the temperatures in the MAAP profile. Therefore, the required instrumentation should not be adversely impacted by loss of ventilation as a result of an ELAP. The licensee also plans to vent the torus via the HCVS to maintain containment parameters below design limits (discussed in Section 3.4.4.2). Hope Creek will receive offsite resources and equipment from an NSRC within 72 hours after the onset of an ELAP event. The NRC staff finds that it is reasonable to expect that the licensee could utilize these resources to reduce or maintain temperatures within containment to ensure that required electrical equipment survives indefinitely. Nonetheless, plant operators will continue to monitor containment parameters and perform additional actions that may be required to reduce containment temperature and pressure.

Based on temperatures remaining below the design limits of equipment, the ability to vent the torus via the HCVS, and the availability of offsite resources, the NRC staff finds that the electrical equipment in the containment should not be adversely impacted by the loss of ventilation as a result of an ELAP event.

Based on its review of the essential station equipment required to support the FLEX mitigation strategy, which are primarily located in the MCR, 250 Vdc HPCI/RCIC battery and battery charger rooms, relay room, inverter room, switchgear room, 125 Vdc battery rooms, RCIC pump room, and containment, the NRC staff finds that the electrical equipment should perform their required functions at the expected temperatures as a result of a loss of ventilation during an ELAP/LUHS event.

3.9.1.2 Loss of Heating

In the FIP, Section 2.6.4 states that the licensee is using an alternative to the criteria in Section 8.3.1 of NEI 12-06 for the storage of FLEX equipment. The licensee is storing some FLEX equipment, such as diesel generators and the diesel-driven FLEX pumps, outdoors instead of in a structure that can provide protection from ice, snow, and extreme cold conditions. Technical Evaluation 80112074-0025, "Outdoor Storage of FLEX Equipment in Extreme Cold and Hot Weather," determined the capability for FLEX equipment to withstand an outside, bounding low temperature of -4 °F. It states that the DGs are capable of being stored outdoors as equipped, and the diesel-driven FLEX pumps are designed to withstand the outside storage conditions. The FLEX DGs are equipped with jacket water heaters, enclosure space heaters, and battery chargers; the diesel-driven FLEX pumps are provided with block heaters and battery trickle chargers. Also, FIP Section 2.6.4 states that the licensee verifies "keep warm" systems are operating during routine checks per procedures HC.OP-DL.ZZ-0006-F1 and HC.OP-DL.ZZ-0007-F1. For example, HC.OP-DL.ZZ-006-F1 verifies battery chargers are in service and keep warm systems are in service December through April for the FLEX 480 Vac diesel generators on the Unit 2 reactor building roof. Therefore, the NRC staff finds the equipment stored outside should be available when called upon, consistent with the licensee's Technical Evaluation 80112074-0025 and its procedures (HC.OP-DL.ZZ-0006-F1 and HC.OP-DL.ZZ-0007-F1), as an alternative to Section 8.3.1 of NEI 12-06.

The 125 Vdc and 250 Vdc battery rooms are located in the interior of the Unit 1 auxiliary building such that outside air temperature should not adversely impact battery performance. At the onset of the event, the Class 1E Battery Rooms would be at their normal operating temperature and the temperature of the electrolyte in the cells would build up due to the heat generated by the batteries discharging and during recharging. Temperatures in the battery rooms are not expected to be sensitive to extreme cold conditions due to their location in the auxiliary building, the concrete walls isolating the rooms from the outdoors, and lack of forced outdoor air ventilation during early phases of the ELAP event. Based on the above, the NRC staff finds that Hope Creek Class 1E station batteries should perform their required functions during the loss of normal heating during an ELAP event.

The two FLEX alternate header pumps are pre-staged in the core spray pump room (Room 4104) of the reactor building. The NRC staff finds that these pumps would not be affected by low outside temperatures because heat would continue to be generated in the reactor building. In addition, hoses that are routed outside and pumps that are located outside would have positive flow. With positive flow, the hoses and pumps would be protected from freezing. Hoses and pumps that are not being used would likely be drained and therefore also protected from freezing. In addition, FIP Section 2.6.4 states that the diesel-driven FLEX pump has more than one strainer assembly. If it becomes clogged from ice, the strainer can be pulled from the river, exchanged, and cleaned. If surface ice is on the river, the suction house can be routed inside icebreakers in front of the SWIS. Therefore, the NRC staff finds that equipment such as batteries, pumps, and hoses should be available to support the FLEX mitigation strategy.

Based on the information above, the NRC staff finds the station equipment required to support the FLEX mitigation strategy should perform the required functions at the expected temperatures as a result of loss of heating during an ELAP event, consistent with NEI 12-06 Section 8.3.2. In addition, the NRC staff finds the licensee's alternative to NEI 12-06 Section 8.3.1 is acceptable. The licensee's Technical Evaluation 80112074-0025 demonstrates that FLEX equipment can be stored outside in cold weather, and the licensee has procedures for monitoring systems that keep this equipment warm.

3.9.1.3 Hydrogen Gas Control in Vital Battery Rooms

An additional ventilation concern that is applicable to Phases 2 and 3 is the potential buildup of hydrogen in the 125 Vdc and 250 Vdc battery rooms as a result of loss of ventilation during an ELAP event. Off-gassing of hydrogen from batteries is only a concern when the batteries are charging. The NRC staff reviewed licensee analysis VTD 432340 to verify that hydrogen gas accumulation in the 125 Vdc and 250 Vdc battery rooms will not reach combustible levels while HVAC is lost during an ELAP. According to the licensee calculations, the hydrogen levels in the 125 Vdc and 250 Vdc battery rooms should remain less than 1 percent. Procedures HC.OP-EO.ZZ-0401(Q) and HC.OP-AB.ZZ-0135(Q) provide guidance to open doors to the 125 Vdc and 250 Vdc battery rooms, battery charger rooms, and other areas. The 250 Vdc battery rooms also have an open fire damper allowing air flow between the battery room and the adjacent electrical equipment area to assist in removing hydrogen.

Based on its review of the licensee's calculation and battery room ventilation strategy, the NRC staff finds that hydrogen accumulation in the Hope Creek 125 Vdc and 250 Vdc battery rooms should not reach the combustibility limit for hydrogen (4 percent) during an ELAP.

3.9.2 Personnel Habitability

The licensee summarizes its personnel habitability evaluation in FIP Section 2.11.1 for the key areas of its FLEX strategy. These key areas are the MCR, reactor building, RCIC room, and battery rooms. The licensee ran a series of Gothic models to determine the temperatures in areas of the reactor building and auxiliary building where access is required to implement FLEX strategies. The licensee summarizes its GOTHIC model results for reactor building areas in Technical Evaluation 80113610-0200, "Evaluation of Hope Creek Gothic Results for Reactor Building FLEX Response," and for auxiliary building areas in Technical Evaluation 80113610-0210, "Evaluation of Hope Creek Gothic Results for Auxiliary Building FLEX Response." In these evaluations, the licensee determined if any compensatory measures are required for personnel access consistent with its heat stress procedure SA-AA-111. The areas evaluated in the reactor building and auxiliary building are described in the sections that follow.

3.9.2.1 Main Control Room

In the FIP, Section 2.11.1 states that the MCR is the only area for which portable ventilation is needed as a compensatory measure. Technical Evaluation 80113610-0210 states that temperature spikes within the first hour to approximately 98 °F and then rises to approximately 100 °F at 6 hours prior to starting a 3,700 standard cubic foot per minute (SCFM) fan using procedure HC.OP-AB.ZZ-0135. With the fan, the temperature remains below 102 °F for the 72-hour duration of the evaluation, and consistent with the heat stress procedure SA-AA-111, the licensee determined stay time is unlimited in the MCR. In the electrical access area (Room 5501), temperature initially reaches 100 °F but then drops after the 3,700 SCFM portable fan is started. Operators perform load stripping by opening breakers in this room. Their actions take about an hour and are completed within the first 5 hours following an ELAP event when the stay time is limited to one hour and 25 minutes. Therefore no additional compensatory actions are required in the electrical access area.

3.9.2.2 Spent Fuel Pool Area

Technical Evaluation 80113610-0200 describes several areas involving SFP operations. It describes actions at air locks, stairways, a corridor, the gamma scan detector area, and the refueling floor laydown area.

Operators run fire hose through the airlocks from the SFP connection to a stairway to provide FLEX alternate header pump discharge for SFP makeup. Although the actions involve high work demand, the licensee determined that results for personnel habitability are acceptable because the actions will take approximately 30 minutes to complete within the first 6 hours of an ELAP event. Temperature remains below a maximum of 96 °F in the various areas. The stay time limit is at least an hour and 45 minutes. For the stairway at the 162 ft elevation, operators also throttle valves for SFP makeup throughout Phases 1 and 2. This action takes less than 30 minutes to complete. At the 162 ft elevation in this stairway, the maximum temperature reaches 108 °F and the stay time limit is an hour and 45 minutes. Therefore, no additional compensatory actions are required in the airlocks or stairway.

Operators access the corridor and gamma scan detector area to connect hose for SFP makeup to the B.5.b connection as an alternate source of water. This action will take less than 30 minutes to complete within the first 13 hours following an ELAP event. The corridor remains below 96 °F for up to 13 hours when the stay time limit is more than two hours. Note, however, if this action were to occur from 13 hours to 30 hours following an ELAP event, then temperature reaches 104 °F in the corridor and the stay time limit is 30 minutes. There would be no reason to access the corridor after 30 hours. For the gamma scan detector area, temperature reaches 92 °F at 27 hours. The stay time limit for 92 °F is more than 3 hours. Therefore, no additional compensatory actions are required for either the corridor or the gamma scan detector area.

In the refueling floor laydown area, operators run hose and attach a nozzle for SFP makeup from the CST or suppression pool. These actions also involve high work demand; however, the area remains below 96 °F for the first 13 hours, which is prior to the initiation of boiling (see SE Section 3.3.4.2 for further discussion of time to boil.). In addition, the actions will take less than 30 minutes to complete within the first 13 hours following an ELAP event; after which personnel access is no longer required in the refueling floor laydown area. The stay time limit is more than 2 hours. Therefore, the licensee determined personnel habitability results are acceptable and no additional compensatory actions are required.

3.9.2.3 Reactor Core Isolation Cooling Room

To ensure RCIC continues to provide service, the equipment area high temperature system isolations are defeated (or bypassed) per Procedure HC.OP-AB.ZZ-0135 (these actions are described in FIP Sections 2.3.1 and 2.11.1.). The licensee will follow their heat stress procedure, SA-AA-111, if any personnel entries are required to this room.

3.9.2.4 Other Reactor Building Areas

In addition to the SFP area and the RCIC room, Technical Evaluation 80113610-0200 describes several areas of the reactor building where operator actions are required to implement the FLEX mitigation strategies. In all cases, no additional compensatory actions are required. In most of the cases, the stay time limit is significantly longer than the time required to perform the actions. Each of these areas is shown in the following table with the licensee's basis for determining personnel habitability results are acceptable. Areas used for normal passage only are not shown in the table because the work demand is low, and the time for passage is short.

Rooms	**Operator Actions**	**Basis for Licensee finding Personnel Habitability Results Acceptable**
Torus Water Clean-Up (TWCU) Room	Operators connect stainless steel hoses for suction and discharge piping and align suction paths for operation of the FLEX alternate header pump.	Temperature reaches 97 °F at 6 hours. The actions take 35 minutes to complete within the first six hours following an ELAP event. The stay time is more than 2 hours.

Rooms	Operator Actions	Basis for Licensee finding Personnel Habitability Results Acceptable
B Core Spray Pump Room	In addition to connecting hoses, personnel operate the FLEX alternate header pump in this room.	Temperature remains below 88 °F initially, but rises to 102 °F at 6 hours and 109 °F at 72 hours. The movement of hoses takes 35 minutes to complete in the first 6 hours following an ELAP event. Stay time is unlimited in the first 6 hours and is at least an hour and 30 minutes afterwards.
D Core Spray Pump Room	Operators align suction paths through the "D" Core Spray Pumps "B" and "D" Suction Crosstie Isolation valve.	The maximum temperature is 90 °F. The actions will take 35 minutes to complete in the first 6 hours following an ELAP event and there is no stay time limit.
Stairway	Alternate power cables for the FLEX alternate header pump are run through this stairway and it is used by operators to access the pump.	Temperature remains less than 94.5 °F for the first 9 hours and reaches a maximum temperature of 97.9 °F at 72 hours. Running cables takes one hour to complete in the first 6 hours following an ELAP event when the stay time limit is more than 2 hours. Afterwards, the stay time limit is an hour and 55 minutes.
Corridor	Operators open the FLEX alternate header Pump suction valve from the CST.	The maximum temperature reached is 88.4 °F and the stay time is unlimited.
RACS Pumps Area	Operators align the FLEX alternate header pump discharge to SW emergency makeup.	During the first 9 hours following an ELAP event, temperature remains below 97 °F. The actions will take 35 minutes in the first 6 hours following an ELAP event when the stay time limit is more than an hour.
RACS Heat Exchanger Area	Operators pull hoses to align the FLEX alternate header pump alternate injection path.	During the first 9 hours following an ELAP event, temperature remains below 97 °F. Pulling hoses will take 35 minutes to complete within the first 6 hours following an ELAP event when the stay time limit is more than an hour.

Rooms	Operator Actions	Basis for Licensee finding Personnel Habitability Results Acceptable
RHR Heat Exchanger Room	Operators pull hoses to align the FLEX alternate header pump alternate injection path.	The maximum temperature reached is 93.8 °F. Pulling hoses will take 35 minutes to complete within the first 6 hours following an ELAP event when the stay time limit is more than 2 hours.
RCIC Pipe Chase	Operators ensure the PCIG isolation valve is open or open the valve manually, if required.	Temperature remains below 130 °F for the first 2 hours following an ELAP event, and the stay time is limited to 15 minutes.
Corridor	Operators run cable for the FLEX air compressor.	Temperature does not rise above 92 °F in the first 9 hours following an ELAP event. The stay time limit is more than 3 hours and the actions are expected to take less than 20 minutes to complete.
Motor Control Center	Operators open and close breakers, run cables for the FLEX air compressor and radio repeaters.	The maximum temperature reached is 91.2 °F. The stay time limit is more than 3 hours and the actions will take 1 hour to complete within the first 6 hours following an ELAP event.
Drywell Access Area	Operators run cables and hoses to align the FLEX air compressor for operation.	The room temperature is below 99 °F at 9 hours. The time limit for this action is 50 minutes and will take less than 20 minutes to complete within the first 6 hours following an ELAP event.
Stairway	Operators open the PCIG isolation valve manually, if required, by gaining access to the PCIG room through this stairway.	Temperature remains below 96 °F for the first 6 hours following an ELAP event. Operators can traverse this stairway in 15 minutes and the stay time limit is more than 2 hours.
Instrument Gas Compressor Room	Operators perform FLEX air compressor valve alignment.	The maximum temperature reached is 93.1 °F. The stay time limit is 4 hours and the actions will take less than 20 minutes to complete within the first 6 hours following an ELAP event.

Rooms	Operator Actions	Basis for Licensee finding Personnel Habitability Results Acceptable
Instrument Gas Compressor Room	Operators perform FLEX air compressor valve alignment.	The maximum temperature reached is 94.8 °F. The stay time limit is more than 2 hours and the actions will take less than 20 minutes to complete within the first 6 hours following an ELAP event.

3.9.2.5 Other Auxiliary Building Areas

In addition to the MCR, Technical Evaluation 80113610-0210 describes several areas in the auxiliary building where operator actions are needed. Personnel habitability in these areas is described in the sections that follow.

Battery Rooms

Technical Evaluation 80113610-0210 describes battery rooms at the 54 ft elevation, 146 ft elevation, and 163 ft elevation of the auxiliary building. The battery rooms at the 163 ft elevation require no operator actions and are not discussed further in this section. At the other elevations, operator actions consist of opening doors and verifying proper operation of battery chargers. In addition, the licensee describes an alternate strategy to connect two 25 ft cables to repower chargers. The licensee determined that the bounding temperature at the 54 ft elevation is 88 °F at 72 hours. The licensee found personnel habitability results acceptable because stay times are unlimited at this temperature. At the 146 ft elevation, the licensee determined two Class 1E Battery Rooms are bounding and found that temperature rises to 92 °F in 4 hours and then to 102 °F at 5 hours. The licensee determined personnel habitability results are acceptable because cables can be connected in about an hour, and this action occurs within the first 5 hours of an ELAP event. Therefore, no additional compensatory actions are required for battery rooms.

Diesel Switchgear Rooms

Technical Evaluation 80113610-0210 describes two diesel switchgear rooms (Rooms 5413 and 5417) in the auxiliary building where operators run FLEX electrical cables. These actions take about an hour and are completed within the first 5 hours of an ELAP event. The licensee's bounding analysis estimates temperature rises to 106 °F at approximately 5 hours and reaches a peak temperature of 113 °F at 72 hours. Technical Evaluation 80113610-0210 specifies opening doors to ensure temperature remains below 113 °F. In addition, it specifies diesel switchgear rooms at the 124 ft elevation are the first to have cable pulls performed per procedure HC.OP-EO.ZZ-0401.

Class 1E Inverter Rooms

Technical Evaluation 80113610-0210 describes two Class 1E inverter rooms (Rooms 5447 and 5448) in the auxiliary building. Work in these rooms involves opening doors, load shedding, and opening and closing breakers. The licensee determined Room 5448 is bounding and reached a maximum temperature of 127.3 °F with doors closed. It therefore requires (per Procedure HC.OP-EO.ZZ-0401) operators to open doors to Room 5448 during an ELAP event. With doors open, the room reaches an upper temperature of 98 °F. At this temperature, the licensee determined personnel have sufficient time to perform their tasks, and no additional compensatory actions are required.

3.9.2.6 Conclusions

The NRC staff finds the above strategies are consistent with NEI 12-06, Section 3.2.2.11, such that station personnel can safely enter the reactor building and auxiliary building and perform the necessary actions to support the FLEX mitigation strategy, during an ELAP event.

3.10 Water Sources

3.10.1 RPV Make-Up

As described in the FIP, the normal suction sources for RCIC, HPCI and the motor-driven FLEX alternate header pumps are the CST and the suppression pool (torus). Both of these sources provide high-quality water for injection into the RPV. The UHS, the Delaware River, provides an indefinite supply of water but is of lower water quality. Hope Creek has incorporated BWR Owners Group (BWROG) guidance into the mitigation strategies to maintain core cooling with river water.

In its FIP, the licensee described that the suppression pool (torus) is part of the primary containment system and is located in the reactor building. The reactor building is designed to withstand the maximum postulated seismic event. In addition, the reactor building is designed to provide protection of the torus from all postulated external hazards including tornadoes. The torus water supply is robust for all external hazards and is the credited water supply for the baseline strategy in the MAAP analyses.

In addition, the licensee described that the CST is the normal source of water for the HPCI and RCIC pumps and can also provide a suction source for the FLEX alternate header pumps. The water volume in the CST is maintained above 276,000 gallons during normal operation. The CST is designed to provide a reserve of 135,000 gallons for HPCI and RCIC use. The CST is located outdoors and is provided with freeze protection. It is a field erected, non-seismic tank supported on a reinforced concrete mat foundation at plant grade level near the reactor building. Although it is not Seismic Category I, the CST was evaluated by the licensee to be seismically adequate to survive the design basis SSE and the ground motion response spectra (GMRS) of the reevaluated seismic hazard.

In its FIP, the licensee described that water from the Delaware River can be supplied via a diesel-driven FLEX pump discharging into the service water system to inject water into the RPV through the service water crosstie flow paths to "A" or "B" RHR system. This source of untreated water would be used in the event that the FLEX alternate header pumps were not available when needed, possibly due to tornado damage to the FLEX DGs on the Unit 2 reactor building roof. The Delaware River supply is also used to show indefinite cooling capacity. The portable diesel-driven FLEX pump will be deployed at approximately 6 hours into the event (or later if the site has experienced flooding, as shown in FIP Table 3), the point at which RCIC performance could begin to degrade due to elevated torus temperatures. The FIP notes that Phase 3 equipment supplied by an NSRC will include water treatment equipment, which would be used to treat the river water.

3.10.2 Suppression Pool Make-Up

The FIP described that suppression pool (torus) level replenishment will be provided by river water from the portable diesel-driven FLEX pump located near the SWIS. The diesel-driven FLEX pump would take suction from the Delaware River and discharge to the service water system to supply water to the torus spray header or the RHR test return valve through the service water crosstie flow paths to "A" or "B" RHR system.

3.10.3 Spent Fuel Pool Make-Up

In its FIP, the licensee described that make-up to the SFP would be provided from a diesel-driven FLEX pump located at the SWIS taking suction from the Delaware River or from the FLEX alternate header pumps taking suction from either the CST (if available) or the torus.

3.10.4 Containment Cooling

As described in its FIP, for Phases 1 and 2, torus venting via the HCVS will be initiated per site procedures to maintain containment parameters below design limits and within the limits that allow continued use of RCIC. Procedures for torus venting as part of FLEX implementation (also known as anticipatory venting) are based on BWROG emergency procedure guidelines/severe accident guidelines (EPG/SAG), revision 3.

For Phase 3, the FIP described that equipment from the NSRC would be utilized to maintain and cool the containment. Four 4.16 kV generators from the NSRC will provide adequate power to energize one safety division and initiate core cooling using RHR with adequate margin remaining to begin torus water cooling.

3.10.5 Conclusions

Based on the evaluation above, the NRC staff concludes that the licensee has developed guidance that, if implemented appropriately, should maintain satisfactory water sources following a BDBEE consistent with NEI 12-06 guidance, as endorsed by JLD-ISG-2012-01, and should adequately address the requirements of the order.

3.11 Shutdown and Refueling Analyses

Order EA-12-049 requires that licensees must be capable of implementing the mitigation strategies in all modes. In general, the discussion above focuses on an ELAP occurring during power operations. This is appropriate, as plants typically operate at power for 90 percent or more of the year. When the ELAP occurs with the plant at power, the mitigation strategy initially focuses on the use of the steam-driven RCIC pump to provide the water to the RPV that is initially needed for decay heat removal. If the plant has been shut down and all or most of the fuel has been removed from the RPV and placed in the SFP, there may be a shorter timeline to implement the makeup of water to the SFP. However, this is balanced by the fact that if immediate cooling is not required for fuel in the reactor vessel, the operators can concentrate on providing makeup to the SFP. The licensee states in FIP Section 2.16 that following a full core offload to the SFP, with the reactor cavity gates in place, the minimum time to boil is just under 7 hours. Also, the time for boil-off to uncover the fuel is about 2 days. The licensee stated that all preparations to install FLEX hoses in the SFP area will be completed within 6 hours after loss of cooling, and that water addition to the SFP will start prior to fuel uncovery.

When a plant is in a shutdown mode in which steam is not available to operate a steam-powered pump such as RCIC (which typically occurs when the RPV has been cooled below about 300 °F), another strategy must be used for decay heat removal. On September 18, 2013, NEI submitted to the NRC a position paper entitled "Shutdown/Refueling Modes" [Reference 38], which described methods to ensure plant safety in those shutdown modes. By letter dated September 30, 2013 [Reference 39], the NRC staff endorsed this position paper as a means of meeting the requirements of the order.

The position paper provides guidance to licensees for reducing shutdown risk by incorporating FLEX equipment in the shutdown risk process and procedures. Considerations in the shutdown risk assessment process include maintaining necessary FLEX equipment readily available and potentially pre-deploying or pre-staging equipment to support maintaining or restoring key safety functions in the event of a loss of shutdown cooling. The NRC staff concludes that the position paper provides an acceptable approach for demonstrating that the licensees are capable of implementing mitigating strategies in shutdown and refueling modes of operation. In Section 2.16 of the FIP, "Shutdown and Refueling Modes Analysis," the licensee informed the NRC staff of its plans to follow the guidance in this position paper. During the audit process, the NRC staff observed that the licensee had made progress in implementing this guidance.

Based on the licensee's incorporation of the use of FLEX equipment in the shutdown risk process and procedures, the NRC staff concludes that the licensee has developed guidance that, if implemented appropriately, should maintain or restore core cooling, SFP cooling, and containment following a BDBEE in shutdown and refueling modes consistent with NEI 12-06 guidance, as endorsed by JLD-ISG-2012-01, and should adequately address the requirements of the order.

3.12 Procedures and Training

3.12.1 Procedures

In its FIP, the licensee described that the inability to predict actual plant conditions that require the use of FLEX equipment makes specific procedural guidance impractical. The FSGs provide guidance that can be employed for a variety of conditions. Clear criteria for entry into FSGs ensures that FLEX strategies are used only as directed for BDBEE conditions, and are not used inappropriately in lieu of existing procedures. When FLEX equipment is needed to supplement EOPs or abnormal operating procedures (AOPs), the EOP or AOP directs the entry into and exit from the appropriate FSG.

The FIP described that FSGs provide instructions for implementing available, pre-planned FLEX strategies to accomplish specific tasks in the EOPs or AOPs. The FSGs are used to supplement (not replace) the existing procedure structure that establishes command and control for the event. If plant systems are restored, exiting the FSGs and returning to normal plant operating procedures will be addressed by the plant's emergency response organization and operating staff, dependent on the actual plant conditions at the time.

The FIP also described that FSG maintenance is performed by operations staff, as described in procedure EM-AA-100-1002. The FSGs have been reviewed and validated by the involved groups to the extent necessary to ensure that implementation of the associated FLEX strategy is feasible. Specific FSG validation was accomplished via table top evaluations and walk-throughs of the guidelines when appropriate.

3.12.2 Training

In its FIP, the licensee described that their training program has been revised to assure personnel proficiency in utilizing FSGs and associated FLEX equipment for the mitigation of BDBEEs is adequate and maintained. These programs and controls were developed and have been implemented in accordance with the Systematic Approach to Training (SAT) process.

The FIP described that initial training has been provided, and periodic training will be provided, to site emergency response leaders on beyond-design-basis BDB emergency response strategies and implementing guidelines. Personnel assigned to direct the execution of the FLEX mitigation strategies for BDBEEs have received the necessary training to ensure familiarity with the associated tasks, considering available job aids, instructions, and mitigation strategy time constraints.

The FIP described that certification of the training simulator fidelity using ANSI/ANS [American National Standards Institute/American Nuclear Society] 3.5, "Nuclear Power Plant Simulators for use in Operator Training," is considered to be sufficient to simulate the initial stages of the BDBEE scenario until the current capability of the simulator model is exceeded. Full scope simulator models will not be upgraded to accommodate FLEX training or drills.

The FIP also described that performance enhancing activities (which may include drills, exercises, tabletop drills, out-of-sequence focused drills, etc.) to provide knowledge and skill development for FLEX responses are outlined in EM-AA-100-1004, "Performance Enhancing Activities Guideline." The licensee follows the training requirements set forth in 10 CFR 50.47(b)(14) and 10 CFR 50 Appendix E Section F.2.j.

3.12.3 Conclusions

Based on the description above, the NRC staff finds that the licensee has adequately addressed the procedures and training associated with FLEX. The procedures have been issued in accordance with NEI 12-06, Section 11.4, and a training program has been established in accordance with NEI 12-06, Section 11.6.

3.13 Maintenance and Testing of FLEX Equipment

As a generic issue, NEI submitted a letter to the NRC dated October 3, 2013 [Reference 40], which included EPRI Technical Report 3002000623, Nuclear Maintenance Applications Center: Preventive Maintenance Basis for FLEX Equipment. By letter dated October 7, 2013

[Reference 41], the NRC endorsed the use of the EPRI report and the EPRI database as providing a useful input for licensees to use in developing their maintenance and testing programs. In its FIP, the licensee stated that they would conduct maintenance and testing of the FLEX equipment in accordance with the industry letter.

The FIP described that FLEX equipment can be used for other purposes as long as controls are put in place to ensure equipment is able to be deployed to the proper locations within the time requirements of the FLEX strategies. Connecting FLEX equipment to plant systems outside of a BDB ELAP may require the Shift Manager/Emergency Coordinator to invoke 10CFR50.54(x) and/or 10CFR73.55(p). The equipment must be returned to the proper storage area if severe weather is predicted or when not in use. Use of portable diesel equipment must be used in accordance with New Jersey Department of Environmental Protection air permits. FLEX equipment must be tracked when alternate use of equipment and connections is permitted using the tracking form contained in OP-HC-108-115-1001.

In its FIP, the licensee described that the exception to this tracking requirement is the earth moving equipment and towing equipment. This equipment is maintained by the site services group and the requirements to separate this equipment by 1,200 feet during severe weather, and when not in use, is controlled by MA-AA-716-002-1002, "Facilities Maintenance Guidelines."

The NRC staff finds that the licensee has adequately addressed equipment maintenance and testing activities associated with FLEX equipment because a maintenance and testing program has been established in accordance with NEI 12-06, Section 11.5.

3.14 Alternatives to NEI 12-06, Revision 0

3.14.1 Reduced Set of Hoses and Cables As Backup Equipment

In its FIP, the licensee took an alternative approach to the NEI 12-06 guidance for hoses and cables. NEI 12-06, Section 3.2.2, states that in order to assure reliability and availability of the FLEX equipment required to meet these capabilities, the site should have sufficient equipment to address all functions at all units on-site, plus one additional spare (i.e., an N+1 capability, where "N" is the number of units on-site). Thus, a single-unit site would nominally have at least two portable pumps, two sets of portable ac/dc power supplies, two sets of hoses and cables, etc. On behalf of the industry, NEI submitted a letter to the NRC [Reference 46] proposing an alternative regarding the quantity of spare hoses and cables to be stored on site. The alternative proposed was that that either a) 10 percent additional lengths of each type and size of hoses and cabling necessary for the N capability plus at least one spare of the longest single section/length of hose and cable be provided or b) that spare cabling and hose of sufficient length and sizing to replace the single longest run needed to support any FLEX strategy. The licensee has committed to following the NEI proposal, and is treating the site as containing three reactors (two Salem units and the HCGS unit). By letter dated May 18, 2015 [Reference 49], the NRC agreed that the alternative approach is reasonable, but that the licensees may need to provide additional justification regarding the acceptability of various cable and hose lengths with respect to voltage drops, and fluid flow resistance. The NRC staff approves this alternative as being an acceptable method of compliance with the order.

3.14.2 Outdoor Storage of FLEX Equipment

NEI 12-06 [Reference 6], Section 8.3.1, states that there are two configurations that could be used to protect FLEX equipment from snow, ice, and extreme cold. Both of these configurations involve storage inside a building. As previously discussed in Section 3.6.1.4 above, for some FLEX equipment the licensee is using outdoor storage without a building. The licensee stated that equipment stored outdoors is designed for outdoor storage in cold environments consistent with normal design practices, e.g., using diesel engine block heaters and space heaters. In addition, the FIP described that the licensee integrated the FLEX capabilities into existing site cold weather procedures and established periodic FLEX equipment status checks that include diesel keep-warm systems and verification that access to equipment is not impaired by snow or ice. The NRC staff finds this to be an acceptable alternative, as the licensee has provided reasonable protection for the associated equipment from snow, ice, and extreme cold. In its FIP, the licensee stated that the FLEX equipment is stored outdoors in a manner that will withstand the effects of a seismic event and located so it is not damaged by other items in a seismic event in accordance with NEI 12-06, Section 5.3.1. The licensee also stated in its FIP that the outdoor storage areas are not protected from tornado missiles, but that the storage locations for necessary FLEX equipment and the spare (N+1) FLEX equipment, such as the FLEX DGs and FLEX SW pumps, are separated by a significant distance to ensure a tornado does not impact both sets at the same time. This separation is discussed in Section 3.6.1.3 of this SE.

3.14.3 Use of Pre-Staged FLEX Equipment

As described in Section 2.3.9.1 of its FIP, the licensee is using two permanently pre-staged FLEX alternate header pumps (one of which is a backup pump), which are located in the B core spray pump room in the Unit 1 reactor building. This is an alternative from the guidance in NEI 12-06, Rev. 0, Section 3.2.2, paragraph 13, which specifies that "...all plants will include the ability to use portable pumps to provide RPV/RCS/SG makeup as a means to provide a diverse capability beyond installed equipment." The licensee does have a strategy to provide makeup using a portable pump as explained in Section 3.2.1.2 above, but the strategy does not work for the flooding event as the portable pump cannot be deployed with floodwaters on the site. The FLEX alternate header pumps are installed in the Unit 1 reactor building, which is a Seismic Category I structure. In addition to the seismic hazard, the reactor building provides protection from external ice, high wind, flooding, and extreme high temperature hazards. The NRC staff performed walkdowns of the licensee's proposed locations for the FLEX pumps during the onsite audit to confirm that the FLEX pumps would be protected from all applicable external hazards. The NRC staff also verified that the primary FLEX pump would be accompanied by a backup (N+1) pump, which will reduce any deployment time needed to hook up the backup pump if the primary pump is unavailable. Given that the installed equipment is located in a structure that is robust to the hazards considered within the scope of Order EA-12-049, and a backup pump is readily available, the NRC staff found the alternative to be acceptable.

As described in Section 2.7 of its FIP, the licensee has permanently prestaged two FLEX DGs on the roof of the unfinished Unit 2 reactor building. This is an alternative from the guidance in NEI 12-06, Rev. 0, Section 3.2.2, paragraph 13. This was done in order to have a primary generator (N) and a spare generator (N+1) above the flood height for hurricane storm surge. These two DGs are reasonably protected from all postulated site hazards except for tornado missiles. In case of damage to these two DGs, the licensee has a third DG in an outdoor storage area that is sufficiently separated from the Unit 2 reactor building that it would not be damaged by a tornado that impacts the Unit 2 reactor building. The licensee stated that FLEX timelines and staffing resources account for the time to deploy this spare DG in a tornado scenario if it is needed. Given that a FLEX generator would be available for all the postulated hazards, the NRC staff found this alternative to be acceptable.

3.14.4 FLEX Electrical Distribution

In its FIP, the licensee identified the FLEX electrical strategy as an alternative strategy. This includes the use of a new FLEX 480 Vac MCC. This is an alternative from the guidance in NEI 12-06, Rev. 0, Section 3.2.2, which states "Electrical diversity can be accomplished by providing a primary and alternate method to repower key equipment and instruments utilized in FLEX strategies." Since some equipment used for FLEX can only be repowered using the single FLEX MCC, there is no alternate method if the FLEX MCC is not available. The FLEX MCC is installed in the Unit 2 auxiliary building, is seismically qualified, and is protected from all postulated external hazards.

The location and design of the FLEX MCC protects it from each of the hazards delineated in NEI 12-06. It also provides a way to implement the mitigation strategies during a flood, considering the inundation water level possible during events such as hurricane storm surge. Due to the robust installation of the FLEX MCC and its protection from all applicable hazards, the NRC staff approves this alternative as being an acceptable method of compliance with the order.

3.14.5 Alternate FLEX Electrical Connection for NSRC CTGs Is Not Available

In its FIP, the licensee identified the FLEX connections for the NSRC CTGs as an alternative strategy. In NEI 12-06, Section 3.2.2, it states "Electrical diversity can be accomplished by providing a primary and alternate method to repower key equipment and instruments utilized in FLEX strategies." As discussed in Section 3.7.3.2 above, the licensee does not have an alternate connection point for the NSRC CTGs. The primary connection point is a permanently installed receptacle enclosure, that the licensee stated was designed to assure that it remains available following a seismic event and is subject to augmented quality requirements. It is located inside the safety-related Seismic Class I auxiliary building and is protected from all applicable hazards. Further, the staff reviewed the plant layout and the applicable hazards and concluded that there is reasonable assurance the licensee can access the connection point following a BDBEE. Therefore, the staff finds this alternative to NEI 12-06 to be acceptable.

In conclusion, the NRC staff finds that although the guidance of NEI 12-06 has not been met, if these alternatives are implemented as described by the licensee, they will meet the requirements of the order.

3.15 Conclusions for Order EA-12-049

Based on the evaluations above, the NRC staff concludes that the licensee has developed guidance to maintain or restore core cooling, SFP cooling, and containment following a BDBEE which, if implemented appropriately, should adequately address the requirements of Order EA-12-049.

4.0 TECHNICAL EVALUATION OF ORDER EA-12-051

By letter dated February 27, 2013 [Reference 24], PSEG submitted its OIP for Hope Creek in response to Order EA-12-051. By letter dated July 22, 2013 [Reference 25], the NRC staff sent a request for additional information (RAI) to the licensee. The licensee provided a response by letter dated August 20, 2013 [Reference 26]. By letter dated November 22, 2013 [Reference 27], the NRC staff issued an ISE and RAI to the licensee.

By letters dated August 22, 2013 [Reference 29], February 25, 2014 [Reference 30], August 26, 2014 [Reference 31], and February 18, 2015 [Reference 32], the licensee submitted status reports for the Integrated Plan and the RAI in the ISE. The Integrated Plan describes the strategies and guidance to be implemented by the licensee for the installation of reliable Spent Fuel Pool Level Instrumentation (SFPLI), which will function following a BDBEE, including modifications necessary to support this implementation, pursuant to Order EA-12-051. By letter dated July 28, 2015 [Reference 35], the licensee reported that full compliance with the requirements of Order EA-12-051 was achieved. By email dated March 10, 2017 [Reference 33], the licensee responded to further NRC questions.

The licensee installed a SFPLI system designed by Mohr Test and Measurement LLC. The NRC staff reviewed the vendor's SFPLI system design specifications, calculations and analyses, test plans, and test reports. The staff issued a vendor audit report on August 27, 2014 [Reference 34].

The staff performed an onsite review of the implementation of SFPLI related to Order EA-12-051. The scope of the review included verification of (a) site's seismic and environmental conditions enveloped by the equipment qualifications, (b) equipment installation met the requirements and vendor's recommendations, and (c) program features met the requirements. By letter dated March 25, 2016 [Reference 17], the NRC issued the report on the licensee's progress. Refer to Section 2.2 above for the regulatory background for this section.

4.1 Levels of Required Monitoring

Attachment 2 of Order EA-12-051 states, in part:

> All licensees identified in Attachment 1 to this Order shall have a reliable indication of the water level in associated spent fuel storage pools capable of supporting identification of the following pool water level conditions by trained personnel: (1) level that is adequate to support operation of the normal fuel pool cooling system [Level 1], (2) level that is adequate to provide substantial radiation shielding for a person standing on the SFP operating deck [Level 2], and (3) level where fuel remains covered and actions to implement make-up water addition should no longer be deferred [Level 3].

In its OIP, the licensee identified the SFP levels of monitoring as follows:

- Level 1 corresponds to the 200 feet (ft.) 0 inches (in.) plant elevation (EL.)

- Level 2 corresponds to the 185 ft. 6 in. EL.
- Level 3 corresponds to the 175 ft. 6 in. EL.

The NRC staff's assessment of the licensee's selection of the SFP levels of monitoring is as follows.

- Level 1: Level 1 at 200 ft. 0 in. EL. is adequate for normal SFP cooling system operation and it is also adequate to ensure the required fuel pool cooling pump net positive suction head (NPSH) as the skimmer surge tanks supply the SFP cooling pumps. This level represents the higher of the two points described in NEI 12-02 for Level 1.
- Level 2: Level 2 was identified by the licensee as 185 ft. 6 in. EL. This level is consistent with the first of the two NEI 12-02 options for Level 2, which is 10 feet (+/- 1 foot) above the highest point of any fuel rack seated in the SFP.
- Level 3: Level 3 was identified by the licensee as 175 ft. 6 in. EL., which is the highest point of any fuel rack seated in the SFP where fuel remains covered; and therefore, consistent with NEI 12-02.

Based on the evaluation above, the NRC staff finds that the licensee's proposed Levels 1, 2 and 3 appear to be consistent with NEI 12-02 guidance, as endorsed by JLD-ISG-2012-03, and should adequately address the requirements of the order.

4.2 Evaluation of Design Features

Order EA-12-051 required that the SFPLI shall include specific design features, including specifications on the instruments, arrangement, mounting, qualification, independence, power supplies, accuracy, testing, and display. Refer to Section 2.2 above for the requirements of the order in regards to the design features. Below is the NRC staff's assessment of the design features of the SFPLI.

4.2.1 Design Features: Instruments

In its OIP, the licensee stated that the Hope Creek SFP primary and backup instrument channels will utilize Guided Wave Radar (GWR) based level measurement technology. The GWR level measurement instruments work based on the Time Domain Reflectometry (TDR) principle. The device transmits low-intensity electromagnetic pulses along a rigid or flexible conductor where pulses move at the speed of light. When the pulses reach the surface of the medium to be measured, a portion of the signal is reflected back to the electronics. The instrument measures the time from when the pulse is transmitted to when it is received; half of the measured time will be equivalent to the distance from the reference point of the device to the surface of the measured process. The time value will be representative of the measured level and converted for use in displaying level information. Two channels will be installed.

In its letter dated July 28, 2015 [Reference 35], the licensee provided sketches of the two level channels (Figures 1a and 1b), which showed the SFP level instrument's measuring range would be from about 200 ft. 6 in. EL. down to about 175 ft. 10 in. EL. The NRC staff notes that the instrument's measuring range covers Levels 1 and 2, but is about 4 inches above the Level 3 setting as described in Section 4.1 above. However, the licensee provided the plant operators the detailed information about the range of the level channel in an annunciator response procedure. There is an annunciator alarm window for FUEL POOL LEVEL HI/LO. The alarm response procedure, HC.OP-AR.ZZ-0013(Q), shows the range of the new level channels (LIT-4670A/B) and provides the information to the operator that at Level 3 (the top of the fuel racks), the level channels are offscale low. Also, the Level 3 setting of 175 ft. 6 in. EL is not used in the FSGs. EOP flow chart 103/104 directs action to be taken for low level in the SFP. If SFP water level cannot be maintained above the Technical Specification minimum level of 199 ft. EL, then SFP makeup is initiated from various sources, including use of the FLEX pumps. The NRC staff considers this to be acceptable, as the operators will be aware that action is needed to add water to the SFP.

The NRC staff finds that the licensee's design, with respect to the number of SFP instrument channels and instrument's measuring ranges, appears to be consistent with NEI 12-02 guidance, as endorsed by JLD-ISG-2012-03, and should adequately address the requirements of the order.

4.2.2 <u>Design Features: Arrangement</u>

Regarding Hope Creek's SFPLI arrangement, in its letter dated August 20, 2013 [Reference 26], the licensee stated, in part, that both the primary and backup channels will be physically separated in accordance with the guidelines provided in NEI 12-02 Revision 1. Specifically, the sensors will be in different corners of the SFP and separated by a distance comparable to the shortest side of the pool. The interconnecting cables that extend from the sensors toward the location of the electronics enclosures will be installed using separate routes and separate, but existing, embedded conduits for transition from the SFP to the first junction point.

The existing embedded conduits in the floor concrete provide a physical barrier to protect from potential missile hazards. From the first junction point until the cable leaves the reactor building, and transitions into the auxiliary building, separate conduit routes are used to protect the cable from potential missile hazards. Both the primary and backup channels displays will be located in the lower relay room of the auxiliary/control building. Each electronics enclosure will provide both a local display and a retransmitted signal to a remote display located in the main control room. In its letter dated July 28, 2015 [Reference 35], the licensee revised the location of the local displays to the lower control equipment room (LCER).

The NRC staff found, and verified by walkdown during the onsite audit, that there is sufficient channel separation between the primary and back-up SFPLI channels' level probe, sensor electronics, and routing cables to provide reasonable protection of the level indication function against missiles that may result from damage to the structure over the SFP.

Based on the evaluation above, the NRC staff finds that the licensee's arrangement for the SFPLI, if implemented appropriately, appears to be consistent with NEI 12-02 guidance, as endorsed by JLD-ISG-2012-03, and should adequately address the requirements of the order.

4.2.3 Design Features: Mounting

Regarding mounting design for the SFPLI probe mounting brackets, in its letter dated July 28, 2015 [Reference 35], the licensee stated that the loading on the mounting devices and the effect of additional weight of the probe and mounting on the refuel floor are evaluated using General Civil-Structural Design Criteria for the HCGS. The loading on the probe mount and probe body includes both seismic and hydrodynamic loading by utilizing HCGS design basis seismic response spectra applicable to the installed location. The static weight load is accounted for in the analytical model performed by the instrument vendor (Mohr) using the methodology provided in Institute of the Electrical and Electronics Engineers (IEEE) standard IEEE 344-2004. The seismic loading response of the probe and mount is modeled by Mohr using finite element modeling software. A detailed computational SFP hydrodynamic model has been developed using ANSYS computational fluid dynamics code. The computational model accounts for multi-dimensional fluid motion, pool sloshing, and loss of water from the SFP. The ANSYS derived fluid motion profile in the pool at the installation point and resultant distributed hydrodynamic loading terms are combined with the calculated seismic loading terms in the finite element model to provide a conservative estimate of the combined seismic and hydrodynamic loading terms for the probe and probe mount for the selected location of the sensor probes.

In its email dated March 10, 1017 [Reference 33], the licensee further stated that the SFPLI probe support structures are anchored to the concrete curb around the SFP above the refueling deck in the Seismic Category I reactor building. The anchor bolts that attach the mounting structure to the refuel floor are safety-related, Seismic Category I. The probe mounting brackets are shown by analysis to withstand SSE and hydrodynamic forces for the specific HCGS configuration. The SPFLI probe structures have been designed in accordance with the HCGS Seismic II/I (two over one) criteria. The HCGS Seismic II/I allowable stresses and loading combinations that account for safe shutdown earthquake loads are the same as those used for Seismic Category I design. The SFPLI probes' seismic classification is II/I and their Quality Assurance (QA) classification is Qs. Items with the Qs safety classification are analyzed seismic and are assumed to be designed to the same dynamic loading as Seismic Category I items. During and after a seismic event (SSE), Qs items will maintain structural integrity. The SFPLI channel components, including the sensor probe, were classified as Qs and Seismic II/I. The mounting of the components is analyzed equivalent to a Seismic Category I item.

Related to the mounting design for other SFPLI equipment and associated components including the electronics enclosures, battery enclosures, and conduit supports, in its letter dated July 28, 2015 [Reference 35], the licensee stated that the electronics and battery packages have been tested to Seismic Category I requirements in accordance with IEEE 344-2004. The spectra used for this testing are substantially greater than the spectra for the LCER where these packages are installed. The electronics, power supply, and battery boxes are mounted using HCGS standard support designs, and all conduits are attached to standard HCGS supports to ensure structural adequacy.

In its email dated March 10, 2017 [Reference 33], the licensee further stated that the SFPLI channel conduit and the electronics, power supply, and battery boxes are mounted per PSEG Standard Raceway Support Drawing E-1406-0 (Q) to ensure structural adequacy. The E-1406-0(Q) supports are designed in accordance with D-2.12, "Seismic Category IE Electrical Raceway Support Systems," as analyzed in corresponding calculations (677-0038 and corresponding series of calculations). The raceway is routed from the reactor building SFP area to the lower relay room in the auxiliary building. This raceway routing is exclusively through Seismic Category I structures and the E-1406-0 supports are mounted to the Seismic Category I building components. The supports for the SFPLI channel electronics, power supply, battery boxes, and conduit are non-safety-related but are designed in accordance with PSEG Drawing E-1406-0, "Raceway Notes, Symbols and Details," using supports analyzed to Seismic Category I criteria and attached to Seismic Category I structures. Therefore, the SFPLI will maintain structural integrity and SFPLI functionality during and after a SSE event.

The NRC staff noted that the licensee adequately addressed the design criteria and methodology used to estimate and test the total loading on the mounting devices, including the design basis maximum seismic loads and the hydrodynamic loads that could result from pool sloshing. The site-specific seismic analyses demonstrated that the SFP level instrumentation's mounting design is satisfactory to allow the instrument to function per design following the maximum seismic ground motion. The assumptions and analytical model used in the sloshing analysis for the sensor mounting bracket are adequate. The staff also noted that the licensee adequately addressed the design inputs and methodology used to qualify the structural integrity of the affected plant structures.

The NRC staff finds that the licensee's proposed mounting design for the SFPLI appears to be consistent with NEI 12-02 guidance, as endorsed by JLD-ISG-2012-03, and should adequately address the requirements of the order.

4.2.4 Design Features: Qualification

4.2.4.1 Augmented Quality Process

Appendix A-1 of NEI 12-02 describes a quality assurance process for non-safety systems and equipment that is not already covered by existing quality assurance requirements. Per JLD-ISG-2012-03, the NRC staff found the use of this quality assurance process to be an acceptable means of meeting the augmented quality requirements of Order EA-12-051.

In its OIP, the licensee stated that augmented quality requirements will be applied to the project for the installation of new components, conduit and cable. If safety-related structures, systems, or components are interfaced or affected, then the appropriate quality requirements will be applied.

The NRC staff finds that, if implemented appropriately, this approach appears to be consistent with NEI 12-02 guidance, as endorsed by JLD-ISG-2012-03, and should adequately address the requirements of the order.

4.2.4.2 Equipment Reliability

Section 3.4 of NEI 12-02 states, in part:

> The instrument channel reliability shall be demonstrated via an appropriate combination of design, analyses, operating experience, and/or testing of channel

components for the following sets of parameters, as described in the paragraphs below:

- conditions in the area of instrument channel components used for all instrument components,
- effects of shock and vibration on instrument channel components used during any applicable event for only installed components, and
- seismic effects on instrument channel components used during and following a potential seismic event for only installed components.

Equipment reliability performance testing was performed to (1) demonstrate that the SFP instrumentation will not experience failures during beyond-design-basis BDB conditions of temperature, humidity, emissions, surge, and radiation, and (2) to verify those tests envelope the plant-specific requirements.

During the vendor audit [Reference 34], the NRC staff reviewed the Mohr SFPLI's qualifications and testing for temperature, humidity, radiation, shock and vibration, seismic, and electromagnetic compatibility. The staff further reviewed the anticipated Hope Creek's seismic, radiological, and environmental conditions to verify the Hope Creek bounding conditions. Below is the staff's assessment of the equipment reliability of Hope Creek SFPLI.

4.2.4.2.1 <u>Radiation, Temperature, and Humidity</u>

<u>Spent Fuel Pool Area</u>

With regard to BDB radiological condition at the SFP area related to the SFPLI qualifications, in its letter dated July 28, 2015 [Reference 35], the licensee stated that a radiation dose analysis was performed to support the radiological assessment requirements defined by NEI 12-02 for the SFP area. The analysis provided dose rates and integrated doses for 7 days post-event with SFP water level at NEI 12-02 Level 3 (i.e., top of fuel racks). The analysis also provided dose rates and integrated doses for 40-year normal operation. The 7-day integrated doses were based on the 100-hour old shutdown core inventories (spent fuel sources), as defined in NEI 12-02. The results from the dose rate analysis (dose rate and total integrated dose) were used as the design criteria supplied to Mohr as part of the PSEG detailed specification. The Mohr SFP-1 level probe assembly materials qualification report is used as the basis to demonstrate reliability of the permanently installed equipment located in the SFP and surrounding area under the BDB radiation conditions.

For the environmental conditions at the SFP area in its letter dated July 28, 2015 [Reference 35], the licensee stated that the level probe assembly materials qualification report demonstrates SFPLI capability for SFP environmental conditions including 7-day BDB conditions of 212 °F and 100 percent relative humidity in the SFP area. In the HCGS evaluation, evaluated conditions exceeded 212 °F with SFP boiling, which is considered to be an extremely unlikely scenario given current plant design and mitigation capabilities. Probe assembly material qualification temperatures in the Mohr report are greater than 212 °F and bound postulated temperatures in the vicinity of the SFP, during either a 72-hour ELAP with FLEX or a 7-day ELAP without FLEX implementation.

Outside of SFP Area

Related to the radiological condition of the LCER, where the primary and back-up SFPLI electronics equipment is located, in its letter dated July 28, 2015 [Reference 35], the licensee stated that the LCER is a mild environment located below the MCR and below the elevation of the operating deck in the fuel handling area. The maximum post-event dose rates and integrated doses for HCGS design-basis accidents are assumed to bound any BDB post-event radiation levels (dose rate and total integrated dose) due to the inherent shielding provided from the structures (concrete floors and walls) between the reactor building and the auxiliary building. The SFPLI electronics utilize commercial off-the-shelf components containing complementary metal oxide semiconductor devices which have been found to be capable of withstanding ionizing radiation dose of up to 1,000 rad as described in EPRI 1021067, "Nuclear Power Plant Equipment Qualification Reference Manual," Rev. 1, and discussed in NRC Regulatory Guide 1.209, "Guidelines for Environmental Qualification of Safety Related Computer Based Instrumentation and Control Systems in Nuclear Power Plants." The limit of 1,000 rad is bounding for a mild environment, such as the LCER, and is used as the basis to demonstrate reliability of the permanently installed electronic equipment.

For the environmental conditions of the LCER, in its letter dated July 28, 2015 [Reference 35], the licensee stated that the LCER is classified as a mild environment in accordance with HCGS environmental design criteria document D7.5, "Hope Creek Generating Station Environmental Design Criteria," with a maximum temperature of 85 °F and maximum relative humidity of 90 percent under design-basis conditions. The maximum temperatures for a BDB ELAP at HCGS assuming implementation of FLEX are calculated utilizing the GOTHIC computational code and documented in Vendor Technical Document 432340. The maximum expected ambient temperature in the room where the electronics will be located is not expected to exceed 115 °F during a 72-hour ELAP event assuming FLEX equipment heat loads, based on the GOTHIC analyses which show calculated temperatures between 105 °F and 114 °F. During a 7-day ELAP scenario without FLEX implementation, the heat loads in the LCER would be reduced and SBO coping actions would be taken (e.g., to establish passive ventilation by opening doors). Therefore, a 7-day ELAP without FLEX is not expected to result in higher temperatures than those calculated for the 72-hour FLEX scenario in the LCER. The temperature and humidity test values used in the Mohr EFP-IL SFPI system test report demonstrate reliable operation of the SFPLI electronics under BDB temperature and humidity conditions during either a 72-hour ELAP with FLEX or a 7-day ELAP without FLEX implementation

The staff finds that the licensee adequately addressed the equipment reliability of the SFPLI with respect to radiation, temperature and humidity. The equipment design limits envelop the anticipated conditions of radiation, temperature, and humidity at Hope Creek during a postulated BDBEE and post event. The equipment environmental testing demonstrated that the SFP instrumentation should maintain its functionality under expected BDB conditions.

4.2.4.2.2 Shock and Vibration

With regard to shock and vibration qualification of the SFPLI, in its letter dated July 28, 2015 [Reference 35], the licensee stated that the shock and vibration test results provided in vendor test reports 1-0410-16, "MOHR SFP-1 Level Probe Assembly Shock and Vibration Test Report," and 1-0410-5, "MOHR EFP-IL SFPI System Shock and Vibration Test Report" meet NEI 12-02 criteria for documentation of resistance of the SFPLI to non-seismic mechanical shock and vibration loading.

The NRC staff noted that the licensee adequately addressed the equipment reliability of the SFPLI system with respect to shock and vibration. The NRC performed an audit at the Mohr facility for shock and vibration testing of the SFPLI sensors and electronics components. The staff found them acceptable. If implemented appropriately, the SFPLI should provide its design functions.

4.2.4.2.3 Seismic

With regard to the SFPLI seismic qualification, in its letter dated July 28, 2015 [Reference 35], the licensee stated that, in order to support seismic qualification of the SFPLI in accordance with NRC Order EA-12-051 requirements and NEI 12-02 criteria, composite seismic Required Response Spectra (RRS) enveloping several nuclear generating stations were developed for use by Mohr. The composite RRS are significantly higher than HCGS RRS as specified in the procurement specification for SFPLI. Mohr used seismic acceleration time history excitations that bound the composite RRS to demonstrate qualification of the level probe assembly in the seismic analysis report. Report 1-0410-9, "MOHR SFP-1 Level Probe Assembly Seismic Analysis Report" (PSEG Calculation 6H4-4097), documents the seismic adequacy of the probe assembly under seismic and hydrodynamic conditions by analysis. This report also documents testing to demonstrate that potential probe contact with the SFP liner would have no adverse effect on either the SFPLI or the SFP liner. Mohr performed structural evaluations using HCGS-specific design criteria and configuration, including seismic acceleration time history excitation that bounds the HCGS safe shutdown earthquake RRS. This HCGS-specific analysis shows that the maximum stresses in the probe are significantly lower than the probe material yield stress. Calculation 6H4-4074, "Probe Mounting for Spent Fuel Pool Level Instrumentation Modification," documents the structural adequacy of the probe mounting bracket. The analysis demonstrates that the probe bracket is adequate to withstand the postulated seismic and hydrodynamic forces for the specific HCGS configuration. The Mohr SFPI system seismic test report (1-0410-6, "MOHR EFP-IL SFPI System Seismic Test Report") documents testing performed for the EFP-IL Signal Processor. The test verified that the signal processor continued to function after being subjected to the required seismic response spectra, proving adequacy of seismic design.

The NRC staff noted that the licensee adequately addressed the equipment reliability of SFPLI with respect to seismic. The SFPLI was tested to the seismic conditions that envelop Hope Creek's design-basis maximum ground motion. Further seismic qualifications of the SFPLI mounting is addressed in Subsection 4.2.3, "Design Features: Mounting," of this evaluation.

The NRC staff finds that Hope Creek SFPLI qualification process is adequate. However, the staff has learned that there were incidents at other nuclear facilities, in which Mohr's SFPLI experienced failures of the filter coil (also called a choke). The staff requested Hope Creek to address the impact of Mohr SFPLI failures on its equipment. The licensee provided a response in an email dated March 10, 2017 [Reference 33], in which it stated that both channels of Hope Creek SFPLI experienced partial failures that were documented in the corrective action program (ref notifications 20693744 for B channel and 20693771 for A channel). The notifications were assigned to corrective maintenance work orders 60124245 and 60124178. Those orders directed the repair of the units and the updating of the system software to version 1.15.3 by Mohr. Both units were returned to Mohr under purchase order 4500764598. Mohr performed the required repairs, the software upgrade, and the factory acceptance test (FAT) on both units and returned the units to Hope Creek for installation, with a certificate of conformance (C of C) and a copy of the unit specific FAT. The C of C and the FAT are retained in PSEG's records management system (DCRMS) under H-1-EC-KCS-0390 (014) (i.e., volume 14 of the Critical Software Package (CSP) for the SFPLI). The licensee installed the repaired units and returned them to service via work orders 60124245 and 60124178.

Qualification Report, "EFP-IL MOD 1 Modification Package," provides the evaluations of the replacement parts. Section 3.2 of this document specifically addresses the choke failure and the solution for the fix. The NRC staff's assessment of EFP-IL MOD 1, Revision 0, dated July 16, 2015, is summarized below.

In EFP-IL MOD 1, Mohr provided evaluation of the following hardware modifications:

- In-place replacement of the miniature T1 surface mount choke on the 01-EFP-IL-50001 board with an equivalent component.
- In-place replacement of the miniature T1 surface mount choke on the 01-EFP-IL-50006 board with an equivalent component.
- Incorporation of a fusible link in the 01-EFP-IL-50204 cable assembly.
- Full electrical isolation added to the 01-EFP-IL-50007 (USB interface) board.

Below is the summary of the vendor's evaluation of the above modifications:

<u>T1 Choke Replacement Evaluation</u>

<u>Temperature and Humidity</u>
The replacement choke has an operating temperature range of -40 degree Celsius (°C) to +85 °C, exceeding the -10 °C to +55 °C requirement. Non-condensing humidity does not alter performance of this component.

<u>Electromagnetic Compatibility (EMC)</u>
There is no change to EMC qualification. The choke demonstrates equivalent or higher impedance to common mode noise.

Shock and Vibration
The mass differences are 0.002% and 0.47% for 01-EFP-IL-50001 enclosure mass and the board mass respectively and 0.0003% and 0.18% for 01-EFP-IL-50006 enclosure mass and the board mass respectively.

Seismic
Qualification by similarity to existing qualified equipment is permitted by the IEEE standard 344-2004. Replacement of the T1 choke does not significantly alter equipment mass, mass distribution, or other mechanical characteristics.

Fusible Link Evaluation:
The 01-EFP-IL-50204 Fusible Link is added to the existing power board power cable. One Fusible Link is used per EFP-IL signal processor.

Temperature and Humidity
The Fusible Link's fuses are rated for -55 °C to +125 °C and 100% relative humidity per MIL-STD-201 Method 106.

Electromagnetic Compatibility (EMC)
There is no change to EMC qualification. The Fusible Link uses insulated wiring and connectors identical in configuration to the remainder of the previously qualified cable assembly and expected emissions are unchanged.

Shock and Vibration
The Fusible Link uses insulated wiring and connectors identical in configuration to the remainder of the cable assembly and is secured using identical tie-down and strain-relief methods which have been previously qualified.

The Fusible Link contributes approximately 0.14% enclosure mass, well within the expected variation of the unmodified EFP-IL signal processor enclosure mass due to manufacturing tolerances of system components.

The connectors are qualified by the manufacturer for vibration conditions per Electronics Industries Alliance standard EIA 364-28 and shock loading at 50g. The connector rated minimum pull force is 8.0 pound-force (lbf) per wire terminal, for a total rating of 80.0 lbf for the 10 wire connector, equivalent to 2086g loading assuming a Fusible Link mass of 17.4 grams.

The Littelfuse fuse lead axial pull force is rated at 7 pounds per MIL-STD-202, which is equivalent to 182 gram static loading per fuse (two fuses per cable), assuming cable mass of 17.4 grams and conservatively neglecting stress shielding by cable wiring and insulation.

Seismic
The Fusible Link contributes approximately 0.14% enclosure mass, well within the expected variation of the unmodified EFP-IL signal processor enclosure mass due to manufacturing tolerances of system components.

Electrical Isolation Evaluation:
The front panel USB board 01-EFP-IL-50007 has been modified through addition of the component to provide galvanic USB isolation and enhance electrostatic discharge protection (±15 kV)

Temperature and Humidity
The additional component is rated for normal operation at -40 °C to +85 °C. The component is a hermetic plastic BGA package that is not susceptible to elevated humidity.

Electromagnetic Compatibility (EMC)
There is no change to EMC qualification. The isolation technology within the additional component is compliant with applicable standards including radiated emissions limit per International Electrotechnical Commission standard IEC 61000/CISPR 22. The device reduces the equipment's already low radiated emissions when the USB device is in use because it isolates and prevents noise on internal data and power lines from propagating to external devices connected to the front-panel USB port. The device is not active when USB devices are not in use.

Shock and Vibration
There is insufficient mass difference to alter the equipment shock and vibration response characteristics. The additional component is a rugged, compact, encapsulated surface-mount BGA package enveloped in size and mass by other components in the system. Surface mount components as a class are not susceptible to required levels of shock and vibration when mounted within the EFP-IL equipment enclosures.

Seismic
The nominal difference in enclosure mass is trivial at 0.014%, well within the expected variation of EFP-IL signal processor enclosure mass due to manufacturing tolerances of system components.

The NRC staff found the vendor adequately addressed the staff's concern with regard to the modified equipment qualifications. The temperature and humidity ratings of the replacement parts envelop the expected BDB environmental conditions of the Hope Creek's LCER areas where the electronics equipment is located. Based on the vendor report, there is no indication that new electromagnetic emissions are introduced by the replacement parts. The mass differences are insufficient to alter the seismic, shock, and vibration response characteristics.

In conclusion, the NRC staff finds the licensee's proposed instrument qualification process appears to be consistent with NEI 12-02 guidance, as endorsed by JLD-ISG-2012-03, and should adequately address the requirements of the order.

4.2.5 Design Features: Independence

In its OIP, the licensee described the SFP level instrument channel's physical independence as follows. Independence will be achieved through physical separation of the final installed devices. The two permanently installed instrument sensors will be separated by a distance comparable to the shortest length of a side of the SFP, to the extent practical, based on the existing SFP geometry and construction. The interconnecting cabling associated with each channel will follow separate and independent routes back to the indicating transmitter (electronics) enclosure. The normal ac power source for each channel will be provided from independent and separate sources.

Related to the SFP level instrument channel's electrical independence, in its letter dated July 28, 2015 [Reference 35], the licensee stated that each channel is provided with power from separate Class 1E power supplies (channel A and channel B) using separate fuse panels (1YF401 and 1YF402). Power is supplied to the fuse panels via 120 Vac vital inverters (1A0481 and 1B0481). Upon loss of 120 Vac, the inverters are supplied power from separate Class 1E 125 Vdc station batteries.

The NRC staff noted, and verified during the walkdown, that the licensee adequately addressed the SFPLI channel independence. The instrument channels' physical separation is further discussed in Subsection 4.2.2, "Design Features: Arrangement." With the licensee's proposed design, the loss of one level instrument channel would not affect the operation of the other channel under BDBEE conditions. The staff finds that the licensee's proposed design, with respect to instrument channel independence, appears to be consistent with NEI 12-02 guidance, as endorsed by JLD-ISG-2012-03, and should adequately address the requirements of the order.

4.2.6 Design Features: Power Supplies

With regard to the SFPLI power supply, in its OIP the licensee stated that the normal power supply for each channel will be provided using separate and independent station 120 Vac power sources that are fed from battery-backed inverters (vital supplies) such that loss of one power source will not result in the loss of both channels. The station batteries providing power to the SFP instrument channels will remain operational through an initial coping period, as developed in accordance with NEI 12-06. If all external power is lost, the instrument channel will be powered from the instrument's battery.

As for the instrument battery's duty cycle, in its FIP the licensee stated that the instrument battery is capable of powering the level indicator for at least 72 hours. In its Mohr audit report [Reference 34], the NRC staff review indicated that the Mohr EFP-I L SFPI instrument battery is capable of at least a seven-day battery life in minimum power mode, if the sample rate is set to 15 samples per hour. In the FIP, the licensee stated that the SFPLI channels will be repowered from the FLEX DGs if necessary.

The NRC staff finds that the licensee's proposed power supply design appears to be consistent with NEI 12-02 guidance, as endorsed by JLD-ISG-2012-03, and should adequately address the requirements of the order.

4.2.7 Design Features: Accuracy

With regard to the SFPLI design accuracy, in its letter dated August 20, 2013 [Reference 26], the licensee stated that the SFPLI system is expected to have a design reference accuracy of better than +/- 1 percent of span and will maintain this accuracy over the entire range of operating conditions, including BDB conditions. It will maintain its design accuracy following a power interruption without the need for recalibration. In its letter dated July 28, 2015 [Reference 35], the licensee further stated that the Mohr EFP-I L SFP system uncertainty analysis shows that the SFPLI exceeds the water level measurement accuracy requirements of NEI 12-02. Power interruption testing has been performed on the Mohr EFP-IL signal processor and back-up battery power source. Test results indicate that no deficits were identified with respect to maintenance of reliable function, accuracy, or calibration as a result of power interruption. The results of testing provided evidence of reliable transition from the normal ac power source to back-up battery without affecting accuracy or calibration. The results of the tests are provided in the Mohr EFP-IL SFPI system power interruption report.

The NRC staff noted that the licensee adequately addressed the SFPLI accuracy design, including the expected instrument channel accuracy performance under both normal and BDB conditions. If implemented properly, the instrument channels should maintain the designed accuracy following a change or interruption of power source without the need of recalibration. The staff finds that the licensee's proposed instrument accuracy appears to be consistent with NEI 12-02 guidance, as endorsed by JLD-ISG-2012-03, and should adequately address the requirements of the order.

4.2.8 Design Features: Testing

With regard to the SFPLI's testing design feature, in its letter dated July 28, 2015 [Reference 35], the licensee stated that calibration can be accomplished using time domain reflectometry to demonstrate the impedance waveform through the transmission cable and connectors from the installed signal processor to the probe are unchanged when compared with as installed configuration. During normal operation, the level instrument automatically monitors the integrity of its level measurement system. All testing can be performed using in-situ capability.

Related to the instrument channel check in its letter dated July 28, 2015 [Reference 35], the licensee stated that channel checks are performed by comparing the level measurements displayed by the primary and backup channels directly to each other as part of routine operator rounds in accordance with HCGS Operations procedures. Level alarms from plant instrumentation provide an additional means of checking SFPLI readings (i.e., when no alarm condition exists and the SFPLI channels are providing normal level readings). The channel checks are currently performed on a weekly basis.

The NRC staff finds the licensee's proposed SFP instrumentation design allows for testing and calibration and appears to be consistent with NEI 12-02 guidance, as endorsed by JLD-ISG-2012-03, and should adequately address the requirements of the order.

4.2.9 Design Features: Display

With regard to the location of the SFPLI display, in its letter dated July 28, 2015 [Reference 35], the licensee stated that the primary and back-up instrument channel displays are in the LCER which is located two levels below the MCR and is easily accessible. The displays can be promptly accessed and viewed by operations staff using a stairwell located immediately outside the MCR. The LCER is a mild environment for postulated design-basis accident (DBA) conditions as stated in HCGS environmental design criteria document D7.5. The maximum post-DBA dose rates and integrated doses for HCGS DBAs are assumed to bound any BDB post-event radiation levels (dose rate and total integrated dose) due to the inherent shielding provided from the structures (concrete floors and walls) between the reactor building and the auxiliary building. The estimated doses in the LCER obtained from SFP drain down conditions at NEI 12-02 Level 3 (top of fuel rack) and exposure to personnel monitoring SFP levels in the LCER are bounded by the DBA radiological conditions. Temperature and humidity have been evaluated for this location using GOTHIC analysis and will not preclude access during BDB ELAP events. Travel time from the MCR to the level displays is approximately 5 minutes based on an informal walk through via accessible paths within the auxiliary building.

The NRC staff finds that the licensee's proposed location and design of the SFPLI displays appear to be consistent with NEI 12-02 guidance, as endorsed by JLD-ISG-2012-03, and should adequately address the requirements of the order.

4.3 Evaluation of Programmatic Controls

4.3.1 Programmatic Controls: Training

In its OIP, the licensee stated that standard plant training processes will be used to identify the population to be trained and to determine both the initial and continuing elements of the required training. Training would be completed prior to placing the instrumentation in service.

The NRC staff finds that the licensee's plan to train personnel in the operation and maintenance of the SFP level instrumentation, including the approach to identify the population to be trained, appears to be consistent with NEI 12-02 guidance, as endorsed by JLD-ISG-2012-03, and should adequately address the requirements of the order.

4.3.2 Programmatic Controls: Procedures

With regard to the Hope Creek procedures related to the SFPLI, in its letter dated July 28, 2015 [Reference 35], the licensee stated that the HCGS SFPLI is subject to PSEG procedures and processes to address operation (both normal and abnormal response), calibration, test, maintenance, and inspection. The specific technical objectives are addressed as follows:

a) Operation (Both Normal and Abnormal Response)

The HCGS operations log for the auxiliary building (HC.OP-DL.ZZ-0006-F1, "HG-Auxiliary Building Log 6") has been revised to include weekly checks of the primary and backup displays in the LCER. The log readings check for SFP water level to be consistent with normal operation, establish a maximum deviation of 0.5 ft. between channels, and initiate corrective actions for unsatisfactory readings. For operator response to abnormal conditions, the HCGS alarm response procedure for SFP level alarms has been revised to provide direction to the operator to check SFP level using the SFPLI displays in the MCR or the LCER. Guidelines for implementing NRC Order EA-02-026 Section B.5.b mitigating strategies have been revised to include a precaution against using radios in the vicinity of the SFP to avoid potentially adverse effects of electromagnetic interference (EMI) on the SFPLI.

b) Calibration

The vendor documents (VTD 432306 Volume 36, 1-0410-12, "MOHR EFP-I L Signal Processor Operator's Manual," VTD 432306 Volume 37, 1-0410-13, "MOHR EFP-I L Signal Processor Technical Manual, and VTD 432306 Volume 38, 1-0410-14, "MOHR SFP-1 Level Probe Assembly Technical Manual") include guidance for preventive and corrective maintenance of the SFPLI. The PSEG preventive maintenance (PM) process includes SFPLI instrument calibration based on vendor recommendations.

c) Test

Testing of the SFPLI electronics and batteries are included in the SFPLI PM process.

d) Maintenance

PM process administrative controls are applicable to the HCGS SFPLI. PM activities include testing, calibration, replacement (e.g., batteries and memory cards) and visual inspection of the probe and head. Administrative controls on SFPLI availability are addressed in OP-HC-108-115-1001, "Operability Assessment and Equipment Control Program." Corrective maintenance administrative controls are also applicable to the HCGS SFPLI. This includes administrative controls developed to determine corrective actions and compensatory measures to address the unavailability of SFPLI and FLEX equipment.

e) Inspection

SFPLI inspections of the sensor probe tube and repairable head are part of the PM process. Vendor documents include guidance for performing inspections as PM activities or as needed to support corrective maintenance.

The NRC staff noted that the licensee adequately addressed the SFP level instrument procedure requirements. The procedures have been established for the testing, surveillance, calibration, operation, maintenance, and abnormal responses for the primary and backup SFP level instrument channels. The staff finds that the licensee's procedure development appears to be consistent with NEI 12-02 guidance, as endorsed by JLD-ISG-2012-03, and should adequately address the requirements of the order.

4.3.3 Programmatic Controls: Testing and Calibration

In its letter dated July 28, 2015 [Reference 35], the licensee described the Hope Creek testing and calibration program as follows. The vendor operator's manual, technical manual for the signal processor, and technical manual for the probe assembly (VTD 432306 Volume 36, 1-

0410-12, "MOHR EFP-I L Signal Processor Operator's Manual," VTD 432306 Volume 37, 1-0410-13, "MOHR EFP-I L Signal Processor Technical Manual, and VTD 432306 Volume 38, 1-0410-14, "MOHR SFP-1 Level Probe Assembly Technical Manual" respectively) provide testing and calibration procedures for the SFPLI. The vendor guidance was used to determine maintenance and test activities in accordance with the HCGS PM process. The following maintenance activities and frequencies have been identified for the SFPLI.

- 6-month diagnostics tests:
  - Memory test
  - Battery test
  - Temperature compensation test
  - Scan test and export logs
- 2-year activities:
  - Battery replacement
  - Memory card replacement
  - Transmitter calibration checks (TDR calibration check, probe and transmission cable health checks)
  - Clock calibration
  - Visual inspection of repairable head

As for the compensatory measures for the SFPLI channel(s) out-of-service, in the email dated March 10, 2017 [Reference 33], the licensee stated that the SFPLI channels are subject to the requirements of OP-HC-108-115-1001, "Operability Assessment and Equipment Control Program," Revision 33, in accordance with NEI 12-02 Section 4.3, "Testing and Calibration." Attachment 17 of OP-HC-108-115-1001 includes both channels of SFPLI as BDBEE mitigation equipment. Section 4.1.1 of OP-HC-108-115-1001 requires screening of corrective action program notifications to determine whether BDBEE equipment is affected. The following actions are directed by OP-HC-108-115-1001, Section 4.1.5, Attachment 7 and Attachment 18:

- If one channel of SFPLI is unavailable, then corrective actions are initiated; compensatory actions are developed and implemented prior to exceeding the 90-day limit for unavailability.

- If both channels of SFPLI are unavailable, then the condition is treated as a loss of FLEX capability. Corrective actions are initiated within 24 hours and compensatory actions are implemented within 72 hours of the loss of FLEX capability.

The licensee further stated that specific compensatory measures and corrective actions would depend on the circumstances associated with the equipment unavailability and would include vendor support and corrective maintenance (including equipment replacement) as appropriate.

The NRC staff noted that the licensee adequately addressed the testing and calibration program to maintain the SFPLI channels availability. The licensee testing and calibration plan appears to be consistent with the vendor recommendations. Additionally, compensatory actions for instrument channel(s) out-of-service appear to be consistent with guidance in NEI 12-02.

Based on the evaluation above, the NRC staff finds that the licensee's proposed testing and calibration program appears to be consistent with NEI 12-02 guidance, as endorsed by JLD-ISG-2012-03, and should adequately address the requirements of the order.

4.4 Conclusions for Order EA-12-051

In its letter dated July 28, 2015 [Reference 35], the licensee stated that it met the requirements of Order EA-12-051 by following the guidelines of NEI 12-02, as endorsed by JLD-ISG-2012-03. In the evaluation above, the NRC staff finds that, if implemented appropriately, the licensee's plans conform to the guidelines of NEI 12-02, as endorsed by JLD-ISG-2012-03. Based on the evaluations above, the NRC staff concludes that if the SFP level instrumentation is installed at Hope Creek according to the licensee's proposed design, it should adequately address the requirements of Order EA-12-051.

5.0 CONCLUSION

In August 2013, the NRC staff started audits of the licensee's progress on Orders EA-12-049 and EA-12-051. The staff conducted an onsite audit in February 2016 [Reference 17]. The licensee reached its final compliance date on November 9, 2016, and has declared that the reactor is in compliance with the orders. The purpose of this SE is to document the strategies and implementation features that the licensee has committed to. Based on the evaluations above, the NRC staff concludes that the licensee has developed guidance and proposed designs that, if implemented appropriately, should adequately address the requirements of Orders EA-12-049 and EA-12-051. The NRC staff will conduct an onsite inspection to verify that the licensee has implemented the strategies and equipment to demonstrate compliance with the orders.

6.0 REFERENCES

1. SECY-11-0093, "Recommendations for Enhancing Reactor Safety in the 21st Century, the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident," July 12, 2011 (ADAMS Accession No. ML11186A950)

2. SECY-12-0025, "Proposed Orders and Requests for Information in Response to Lessons Learned from Japan's March 11, 2011, Great Tohoku Earthquake and Tsunami," February 17, 2012 (ADAMS Accession No. ML12039A103)

3. SRM-SECY-12-0025, "Staff Requirements – SECY-12-0025 - Proposed Orders and Requests for Information in Response to Lessons Learned from Japan's March 11, 2011, Great Tohoku Earthquake and Tsunami," March 9, 2012 (ADAMS Accession No. ML120690347)

4. Order EA-12-049, "Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events," March 12, 2012 (ADAMS Accession No. ML12054A736)

5. Order EA-12-051, "Order Modifying Licenses with Regard to Reliable Spent Fuel Pool Instrumentation," March 12, 2012 (ADAMS Accession No. ML12054A679)

6. Nuclear Energy Institute document NEI 12-06, "Diverse and Flexible Coping Strategies (FLEX) Implementation Guide," Revision 0, August 21, 2012 (ADAMS Accession No. ML12242A378)

7. JLD-ISG-2012-01, "Compliance with Order EA-12-049, Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events," August 29, 2012 (ADAMS Accession No. ML12229A174)

8. Nuclear Energy Institute document NEI 12-02, "Industry Guidance for Compliance with NRC Order EA-12-051, To Modify Licenses with Regard to Reliable Spent Fuel Pool Instrumentation," Revision 1, August 24, 2012 (ADAMS Accession No. ML12240A307)

9. JLD-ISG-2012-03, "Compliance with Order EA-12-051, Order Modifying Licenses with Regard to Reliable Spent Fuel Pool Instrumentation," August 29, 2012 (ADAMS Accession No. ML12221A339)

10. Letter from PSEG to NRC, "PSEG Nuclear LLC's - Overall Integrated Plan for the Hope Creek Generating Station in Response to March 12, 2012 Commission Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events (Order Number EA-12-049)," February 27, 2013 (ADAMS Accession No. ML13059A272)

11. Letter from PSEG to NRC, "PSEG Nuclear LLC's First Six-Month Status Report for the Hope Creek Generating Station In Response to March 12, 2012 Commission Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-

Design-Basis External Events (Order Number EA-12-049)," August 22, 2013 (ADAMS Accession No. ML13235A096)

12. Letter from PSEG to NRC, "PSEG Nuclear LLC's Second Six-Month Status Report for the Hope Creek Generating Station In Response to March 12, 2012 Commission Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events (Order Number EA-12-049)," February 25, 2014 (ADAMS Accession No. ML14058A229)

13. Letter from PSEG to NRC, "PSEG Nuclear LLC's Third Six-Month Status Report for the Hope Creek Generating Station In Response to March 12, 2012 Commission Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events (Order Number EA-12-049)," August 26, 2014 (ADAMS Accession No. ML14239A326)

14. Letter from PSEG to NRC, "PSEG Nuclear LLC's Fourth Six Month Status Report for the Hope Creek Generating Station In Response to March 12, 2012 Commission Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events (Order Number EA-12-049)," February 18, 2015 (ADAMS Accession No. ML15051A256)

15. Letter from Jack R. Davis (NRC) to All Operating Reactor Licensees and Holders of Construction Permits, "Nuclear Regulatory Commission Audits of Licensee Responses to Mitigation Strategies Order EA-12-049," August 28, 2013 (ADAMS Accession No. ML13234A503)

16. Letter from Jeremy S. Bowen (NRC) to Thomas Joyce (PSEG), "Hope Creek Generating Station – Interim Staff Evaluation Relating to Overall Integrated Plan in Response to Order EA-12-049 (Mitigation Strategies)," February 11, 2014 (ADAMS Accession No. ML13365A253)

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Date: June 30, 2017

HOPE CREEK GENERATING STATION – SAFETY EVALUATION REGARDING IMPLEMENTATION OF MITIGATING STRATEGIES AND RELIABLE SPENT FUEL POOL INSTRUMENTATION RELATED TO ORDERS EA-12-049 AND EA-12-051 DATED JUNE 30, 2017

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DATE	6/9/17	6/30/17	

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