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

December 13, 2018

Mr. Bryan Hanson
Senior Vice President
Exelon Generation Company, LLC
President and Chief Nuclear Officer
Exelon Nuclear
4300 Winfield Road
Warrenville, IL 60555

SUBJECT: QUAD CITIES NUCLEAR POWER STATION, UNITS 1 AND 2 – SAFETY EVALUATION REGARDING IMPLEMENTATION OF MITIGATION STRATEGIES AND RELIABLE SPENT FUEL POOL INSTRUMENTATION RELATED TO ORDERS EA-12-049 AND EA-12-051 (CAC NOS. MF1048, MF1049, MF1052, AND MF1053; EPID NOS. L-2013-JLD-0019 AND L-2013-JLD-0020)

Dear Mr. Hanson:

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 28, 2013 (ADAMS Accession No. ML13060A420), Exelon Generation Company, LLC (Exelon, the licensee) submitted its OIP for Quad Cities Nuclear Power Station, Units 1 and 2 (Quad Cities), 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 enclosed safety evaluation. 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 November 22, 2013 (ADAMS Accession No. ML13220A351), and June 25, 2015 (ADAMS Accession No. ML15156B134), the NRC issued an Interim Staff Evaluation (ISE) and an audit report, respectively, on the licensee's progress. By letter dated August 14, 2018 (ADAMS Accession No. ML18228A539), Exelon reported that Quad Cities, Units 1 and 2 were in full compliance with Order EA-12-049, and submitted a Final Integrated Plan.

By letter dated February 28, 2013 (ADAMS Accession No. ML13060A124), the licensee submitted its OIP for Quad Cities, Units 1 and 2, 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 enclosed safety evaluation. By letters dated October 9, 2013 (ADAMS Accession No. ML13275A121), and June 25, 2015 (ADAMS Accession No. ML15156B134), the NRC staff issued an ISE and an 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 May 7, 2015 (ADAMS Accession No. ML15127A386), Exelon 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 at Quad Cities, Units 1 and 2.

The enclosed safety evaluation provides the results of the NRC staff's review of Exelon's strategies for Quad Cities, Units 1 and 2. The intent of the safety evaluation is to inform Exelon 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, "Inspection of the Implementation of Mitigation Strategies and Spent Fuel Pool Instrumentation Orders and Emergency Preparedness Communication/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 Peter Bamford, Beyond-Design-Basis Management Branch, Quad Cities Project Manager, at 301-415-2833, or by e-mail at Peter.Bamford@nrc.gov.

Sincerely,

Brett Titus

Brett A. Titus, Acting Chief
Beyond-Design-Basis Management Branch
Division of Licensing Projects
Office of Nuclear Reactor Regulation

Docket Nos.: 50-254 and 50-265

Enclosure:
Safety Evaluation

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TABLE OF CONTENTS

4.4 Conclusions for Order EA-12-051

5.0 CONCLUSION

6.0 REFERENCES

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

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

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

EXELON GENERATION COMPANY, LLC

QUAD CITIES NUCLEAR POWER STATION, UNITS 1 AND 2

DOCKET NOS. 50-254 AND 50-265

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 [Reference 5], the NRC also issued Order EA-12-051, "Order Modifying Licenses With Regard to Reliable Spent Fuel Pool Instrumentation". 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

Enclosure

(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 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 [Reference 2], 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," 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 December 10, 2015 [Reference 6], following submittals and discussions in public meetings with NRC staff, the Nuclear Energy Institute (NEI) submitted document NEI 12-06, Revision 2, "Diverse and Flexible Coping Strategies (FLEX) Implementation Guide," to the NRC to provide revised 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, Revision 2, and on January 22, 2016 [Reference 7], issued Japan Lessons-Learned Directorate (JLD) Interim Staff Guidance (ISG) JLD-ISG-2012-01, Revision 1, "Compliance with Order EA-12-049, Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events,", endorsing NEI 12-06, Revision 2, with exceptions, additions, and clarifications, as an acceptable means of meeting the requirements of Order EA-12-049, and published a notice of its availability in the *Federal Register* (81 FR 10283).

2.2 Order EA-12-051

Order EA-12-051 [Reference 5], Attachment 2, 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 [Reference 8], 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 to the NRC to provide specifications for an industry-developed methodology for compliance with Order EA-12-051. On August 29, 2012 [Reference 9], the NRC staff issued its final version of JLD-ISG-2012-03, "Compliance with Order EA-12-051, Reliable Spent Fuel Pool Instrumentation", 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 <u>TECHNICAL EVALUATION OF ORDER EA-12-049</u>

By letter dated February 28, 2013 [Reference 10], Exelon Generation Company, LLC (Exelon, the licensee) submitted an Overall Integrated Plan (OIP) for Quad Cities Nuclear Power Station, Units 1 and 2 (Quad Cities), in response to Order EA-12-049. By letters dated August 28, 2013 [Reference 11], February 28, 2014 [Reference 12], August 28, 2014 [Reference 13], February 27, 2015 [Reference 14], August 28, 2015 [Reference 15], February 26, 2016 [Reference 16], August 26, 2016 [Reference 17], February 28, 2017 [Reference 18], August 28, 2017 [Reference 19], and February 28, 2018 [Reference 20], the licensee submitted six-month updates to the OIP. By letter dated August 28, 2013 [Reference 21], 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 22]. By letters dated November 22, 2013 [Reference 23], and June 25, 2015 [Reference 24], the NRC issued an Interim Staff Evaluation (ISE) and audit report, respectively, on the licensee's progress. By letter dated August 14, 2018 [Reference 25], Exelon reported that Quad Cities, Units 1 and 2 were in full compliance with Order EA-12-049, and submitted a Final Integrated Plan (FIP).

3.1 <u>Overall Mitigation Strategy</u>

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.

Both units at Quad Cities are General Electric (GE) boiling-water reactors (BWRs), Model 3, with Mark I containments. The licensee's three-phase approach to mitigate a postulated ELAP event, as described in the FIP, is summarized below.

At the onset of an ELAP both reactors are assumed to trip from full power. The main condenser is unavailable due to the loss of circulating water. Decay heat is removed when the electromatic relief valves/safety relief valves (ERVs/SRVs) open on high pressure and dump steam from the reactor pressure vessel (RPV) to the suppression pool located in the primary containment. Makeup to the RPV is provided by the reactor core isolation cooling (RCIC) turbine-driven pump. Because the contaminated condensate storage tanks (CCSTs) are not fully robust, the licensee's mitigating strategy assumes that the RCIC pump suction realigns to the suppression pool. Within approximately 10 minutes, the operators take manual control of the ERVs and begin a controlled cooldown and depressurization of the RPV. The cooldown is stopped when RPV pressure reaches a control band of 150 to 250 pounds per square inch gauge (psig), in order to ensure sufficient steam pressure to operate the RCIC pump. When the suppression chamber (torus) reaches a predetermined pressure setpoint, the hardened containment vent system (HCVS) will be used to vent the suppression chamber in order to mitigate the suppression pool temperature rise and allow the RCIC system to continue to function. The RPV makeup will continue to be provided from the RCIC system until a transition to Phase 2 methods is required.

When the RCIC system is no longer available, the preferred RPV makeup supply in Phase 2 comes from a seismically-designed well. The well head has power connections for a FLEX diesel generator (DG) to operate an installed submerged pump motor. This well pump can then supply water to the RPV on both units via fire hose with connections to installed robust plant systems. As a backup to the well pump, the licensee's plan has provisions to supply water from the discharge bay to the RPV's on both units using a FLEX diesel-driven pump.

Both reactors have Mark I containments. The licensee performed a containment evaluation and determined that opening the suppression chamber vent to atmosphere will allow containment temperature and pressure to stay within acceptable levels to support indefinite coping.

Each unit at Quad Cities has a SFP located on the refuel floor of the secondary containment structure. The two pools are normally connected hydraulically via an open transfer canal such that they effectively act as one volume. To maintain SFP cooling capabilities, the licensee plans to use the same pump as is used for Phase 2 RPV makeup. This pump (seismic well pump or diesel-driven FLEX pump) will be available to provide SFP makeup within approximately 12 hours of the initiating event. The pools will initially heat up due to the unavailability of the normal cooling system. The licensee has calculated that, for a normal heat load, boiling could start at approximately 13.5 hours after the start of the ELAP. With this heat load, the water level would drop to within 12 feet of the top of the fuel racks in approximately 63 hours, and to the top of the fuel in approximately 147 hours, if makeup is not provided. The licensee's FIP timeline shows that SFP makeup is available well before reaching either of these levels. To provide makeup to the SFPs, the licensee has multiple strategies that can be used. The primary strategy uses a combination of installed piping and hoses connected to the same sources (well pump or FLEX pump aligned to discharge bay) as are used in the RPV makeup strategy. The licensee's alternate strategy uses hoses to provide either direct makeup or spray to each pool.

The operators will perform dc bus load shed to extend safety-related battery life sufficient to allow time for the deployment of a FLEX DG for each unit. An initial load shed is initiated within approximately 5 minutes of the event and a deeper load shed is initiated approximately 60 minutes into the event. The licensee estimates that the load shed activities will be completed within approximately 90 minutes of the event initiation. Following the load shed and prior to battery depletion, two 500-kilowatt (kW), 480 volt alternating current (Vac) DGs will be deployed, one for each unit. These DGs will be used to repower essential battery chargers and are expected to be operational within approximately 5 hours of ELAP initiation.

In addition, a National SAFER [Strategic Alliance for FLEX Emergency Response] Response Center (NSRC) will provide high capacity pumps and large combustion turbine generators (CTGs) which could be used to provide spares or backups to the Phase 2 equipment and to restore selected plant systems.

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 2, 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 event presumes that, per endorsed guidance from NEI 12-06, both units 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. Maintenance of sufficient RPV inventory, despite steam release from the ERVs/SRVs and ongoing system leakage, 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 event are discussed in further detail below. The licensee's strategy for ensuring compliance with Order EA-12-049 for conditions where one or more units are shut down or being refueled is reviewed separately in Section 3.11 of this safety evaluation.

3.2.1 Core Cooling Strategy and RPV Makeup

3.2.1.1 Phase 1

According to the licensee's FIP, the initial injection of cooling water into the RPV will be accomplished with an automatic initiation of the high-pressure coolant injection (HPCI) and RCIC systems. Once water level is restored, the HPCI system will be secured, but would remain available to back up the RCIC system. The RCIC system will then be used to maintain water level. Because the turbine for the pump is driven by steam from the RPV, operation of the RCIC system further assists the ERVs with RPV pressure control. The RCIC system suction on each unit is initially lined up to the CCSTs and will pump water into the core from the CCSTs, if available. Since the CCSTs are not fully robust, the licensee's strategy assumes that the RCIC pump will take suction from the suppression pool.

According to the licensee's FIP, pressure control of the RPV is accomplished using the ERVs which are actuated by power from the Class 1E dc buses. Within 10 minutes after the initiation of the event, operators will utilize the ERV's to depressurize at a rate of less than 80 degrees Fahrenheit (°F) per hour. The RPV pressure is lowered and then maintained in a control band between 150 psig and 250 psig to allow for continued operation of the RCIC system.

According to the licensee's FIP, station batteries and the Class 1E dc distribution system provide power to the RCIC systems and instrumentation. An initial load shed begins about 5 minutes after the initiation of the event and is concluded about 30 minutes after initiation of the event. For an ELAP, an extended dc load shed is started approximately 1 hour into the event and is completed by 1.5 hours after the event starts. This load shedding will extend the battery capacity to power the Phase 1 systems and instrumentation to allow time for the FLEX DGs to be deployed.

3.2.1.2 Phase 2

The Phase 2 strategy will include deployment of a portable 480 Vac FLEX DG for each unit. This DG will be positioned at a designated location and temporary cables will be run to connection panels that supply the selected battery chargers. These chargers ensure that continued dc power is available to support operation of the ERVs and the RCIC system. The FLEX DG will also provide power to selected valves that will be aligned to support the Phase 2 RPV injection strategy.

According to the licensee's FIP, the RCIC system will continue to be used until RPV pressure requires a transition to Phase 2 methods. The licensee's preferred option for Phase 2 is to use an installed submersible FLEX well pump powered by a FLEX DG. The discharge of the FLEX well pump will be routed through hoses to a FLEX distribution header. From the distribution header, hoses will be used to establish a flow path to the residual heat removal (RHR) systems on each unit, which will allow injection into the RPVs, and to the suppression pools if desired. As a backup, the licensee's plan has provisions to deploy a diesel-driven FLEX pump that can take a suction from the circulating water discharge bay. If used, this pump's discharge will be routed to the same FLEX distribution header as is used by the well pump. Either the well pump or the diesel-driven FLEX pump can supply sufficient flow to support the makeup requirements for both units. The distribution header allows makeup to be routed to various pathways for injection. Nominally, RPV makeup requirements are approximately 196 gallons per minute (gpm) per unit. If suppression pool makeup is desired, the flow requirement would be approximately 88.5 gpm per unit. Suppression pool makeup is not needed simultaneously with RPV makeup.

Core cooling is supported by an early suppression chamber venting strategy using the HCVS. This action will vent the suppression chamber when it reaches approximately 10 psig, which is projected to occur approximately 5.3 hours into the event. The venting operation will help to maintain suppression pool temperatures less than approximately 230°F, which should support long-term RCIC operation.

3.2.1.3 Phase 3

According to the licensee's FIP, the Phase 3 strategy would be to maintain and supplement/replace the Phase 2 strategy with Phase 3 equipment. The Phase 3 equipment begins to arrive within 24 hours of the NSRC notification. This equipment can be connected to replace Phase 2 components, as required. According to the licensee's FIP, the majority of the equipment that will be arriving from the NSRC can utilize the connection points established for Phase 2. The NSRC equipment will include a hydraulically-driven submersible booster pump. This booster pump would be used in combination with the diesel-driven FLEX pump (or an NSRC pump) in specific scenarios where the water level in the circulating water discharge canal could be low.

3.2.2 Variations to Core Cooling Strategy for Flooding Event

The licensee's core cooling strategy for a Mississippi River-based flooding event differs from the base strategy. In this case, similar to the design-basis strategy described in Section 3.4.1.1 of the Updated Final Safety Analysis Report (UFSAR) [Reference 28], the licensee would use the projected flood warning time to shut down both units, remove the drywell and RPV heads, and flood the refueling cavities with water prior to the arrival of flood waters above the site grade. Independently powered makeup pumps would be pre-positioned at a location above the projected flood elevation such that they would be able to use the flood waters as a suction source to provide makeup water into the refueling cavities to compensate for evaporative cooling loss.

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 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

Phase 1

Section 3.3.4.1 of the licensee's FIP describes the RCIC system as consisting of one turbine-driven pump, one condensate pump, one vacuum pump, a gland seal barometric condenser, automatic valves, control devices for this equipment, and sensors and logic circuitry. The RCIC pump takes suction from the CCSTs and utilizes reactor steam to drive the turbine, which is exhausted into the suppression pool or uses the suppression pool as a backup. The CCSTs are not credited for FLEX strategies. According to the Quad Cities UFSAR, Section 5.4.6, all components necessary for initiating operation of the RCIC system are completely independent of auxiliary ac power, plant service air, and external cooling water. The system requires only dc power from the station battery to operate the necessary valves. According to the licensee's FIP, the RCIC system logic relies on the 125 volts-dc (Vdc) Bus 1A-2 and 125 Vdc Division 2 systems. Motive power for the valves that must change state to mitigate the ELAP event are powered from the Division 2 250 Vdc system. The Reactor Building is the location of the RCIC system. The licensee's FIP also indicates that the RCIC system can be operated manually in accordance with a site procedure should a loss of dc power to the control logic occur. The FIP also states that for an ELAP event with a seismic initiator, the RCIC system will operate under these conditions. Based on the licensee's FIP description and the location of the RCIC system in a Seismic Category I building consistent with NEI 12-06, Section 3.2.2, the NRC staff finds that the RCIC system for each unit is robust and should be available at the start of an ELAP event consistent with NEI 12-06, Section 3.2.1.3.

The source of the RPV makeup water is from the suppression chamber (torus). The suppression chamber can supply the RCIC system for RPV makeup for at least the first 5.5 hours of the ELAP event. According to the Quad Cities UFSAR, Section 3.7.2, the suppression chamber is safety-related and it is located in the Reactor Building, which is protected from all applicable external hazards. Based on the licensee's FIP and UFSAR descriptions, the NRC staff finds that the suppression chamber is robust and should be available at the start of an ELAP event, consistent with NEI 12-06, Section 3.2.1.3.

For the postulated ELAP event, Section 3.3.1.1 of the licensee's FIP describes the strategy for RPV pressure control and decay heat removal by operation of four ERVs and one SRV on each unit, which are installed on the main steam lines inside the drywell. The licensee's FIP indicates that the actuation methods for these valves require 125 Vdc battery power. In addition, the SRVs on each unit require a pneumatic supply for the valve to operate. The ERVs and SRVs are located in the respective unit's Reactor Building, which is robust against all applicable external hazards. According to the licensee's UFSAR, Sections 3.9 and 5.2.2, seismic considerations were incorporated into the valves' design, along with the associated piping and components. This includes the pneumatic supply for the SRVs. Based on the FIP and UFSAR descriptions, the NRC staff finds the ERVs and SRVs, along with their support systems, to be robust and should be available at the start of an ELAP event consistent with NEI 12-06, Section 3.2.1.3.

Phase 2

The source of water for the licensee's RPV makeup strategy in Phase 2 transitions from the RCIC system to the FLEX seismic deep well or the circulating water discharge bay.

Operators are directed by FLEX support guidelines (FSGs) to align the discharge of the FLEX seismic deep well pump to the FLEX distribution header as the primary means for RPV, suppression pool, and SFP makeup. For use of the circulating water discharge bay, a portable diesel-driven FLEX pump is deployed to that location. In either case, the well pump or the FLEX diesel-driven pump will discharge into the FLEX distribution header, which is aligned to the RHR System. The RHR system is safety-related and therefore robust. The mechanical connections for the FLEX seismic deep well pump and FLEX diesel-driven pump are described in Section 3.7.3.1 of this safety evaluation. The seismic well is robust for the postulated external events except for the high wind hazard. However, the circulating water discharge bay should be available following a high wind event. In addition, for a seismic event, the licensee's FIP presents the discharge bay as an alternative to NEI 12-06 and is described and evaluated in Section 3.14.1 of this safety evaluation.

Phase 3

The licensee's Phase 3 RPV inventory strategy does not rely on any additional installed plant SSCs other than those discussed in Phase 1 and 2.

3.2.3.1.2 Plant Instrumentation

The licensee's plan is to monitor instrumentation in the main control room (MCR) and by alternate means to support the FLEX cooling strategy. The instrumentation is initially powered by station batteries and will be maintained for indefinite coping via battery chargers powered by the FLEX DGs. A more detailed evaluation of the instrumentation power supply is contained in Section 3.2.2.6 of this safety evaluation.

As described in the FIP, the following instrumentation will be relied upon to support the FLEX strategy:

- RPV level
- RPV pressure
- Drywell pressure
- Suppression pool level
- Suppression pool pressure
- Suppression pool temperature

These instruments can be monitored from the MCR. According to the licensee's FIP, alternate methods are available to monitor these parameters locally, as directed by an FSG. The staff concludes that this plan provision meets the guidance contained in NEI 12-06, Section 5.3.3.1.

The NRC staff reviewed the instrumentation parameters identified by the licensee to support its core cooling strategy and determined that they are consistent with the recommendations specified in the endorsed guidance of NEI 12-06.

3.2.3.2 Thermal-Hydraulic Analyses

The licensee concluded that its mitigating strategy for reactor core cooling would be adequate based, in part, on thermal-hydraulic analysis performed using Version 4 of the Modular Accident Analysis Program (MAAP). 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 safety evaluation focuses on the licensee's analysis of reactor core cooling. The NRC staff's review of the licensee's analysis of containment thermal-hydraulic behavior is provided subsequently in Section 3.4.4.2 of this safety 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 analyses of the ELAP event using Version 4 of the MAAP code (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 [TRAC/RELAP (Transient Reactor Analysis Code/Reactor Excursion and Leak Analysis Program) Advanced Computational Engine] 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, the EPRI issued a technical report entitled "Use of Modular Accident Analysis Program (MAAP) in Support of Post-Fukushima Applications" [Reference 47]. 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 the 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 48], 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 the EPRI to support consistency in individual licensee's responses to the limitations from the endorsement letter. In particular, based upon 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 a 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 analysis calculated that the licensee would maintain the collapsed liquid level in the RPV about 100 inches above the top of the active fuel region throughout the analyzed ELAP event. By maintaining the reactor core fully covered with water, adequate core cooling is assured for this event. Additionally, the licensee'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, the licensee's analysis calculated that the reactor core remains submerged throughout the ELAP event; this is consistent with the staff's expectation that the 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 makeup 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. 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.

The licensee's calculations for Quad Cities assumed a primary system leakage rate of 42 gpm at full reactor pressure. This leakage rate includes 18 gpm per recirculation pump seal (36 gpm total for two pumps) postulated in accordance with NRC Generic Letter 91-07, "GI-23, 'Reactor Coolant Pump Seal Failures' and its Possible Effect on Station Blackout" [Reference 49], which assumes that no gross seal failure occurs. The postulated primary system leakage rate also accounts for 5 gpm of unidentified leakage and 1 gpm of identified leakage. The RCIC pump capability on each unit can accommodate this leak rate, plus steaming decay heat removal, with margin. The Phase 2 FLEX pumps' capability allows for makeup to both units' RPVs, as well as the SFPs, and provides margin to the assumed leakage rates during the event.

In the MAAP analysis, the licensee discussed system response to the variation of seal leakage rate as a function of RPV pressure in the thermal hydraulic simulation. The initial total leakage rate was assumed to be 42 gpm. As the RPV was depressurized the seal leakage rate was reduced. The licensee concluded that the RPV water level continued to be above the top of the active fuel throughout the simulation period.

Considering the above factors, the NRC staff concludes that the leakage rate assumed by the licensee is reasonable. The staff further notes that gross seal failures are not anticipated to occur during the postulated ELAP event. As is typical of the majority of U.S. BWRs, Quad Cities 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, and the other pumps used for core cooling in its FLEX strategy have a similar functional capability and margin well above the expected leakage rate.

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 <u>Shutdown Margin Analyses</u>

As described in Quad Cities UFSAR, Section 4.3.2.1.3, the control rod system is designed to provide adequate control of the maximum excess reactivity anticipated during the fuel cycle operation. Shutdown capability is evaluated assuming a xenon-free core at ambient temperature, which represents the condition of maximum fuel reactivity. Quad Cities Technical Specification Section 1.1 further clarifies that shutdown margin is to be calculated for a cold, xenon-free condition and assumes that all control rods are fully inserted except for the single control rod of highest reactivity worth, which is assumed to be fully withdrawn.

Based on the NRC staff's audit review, the licensee's ELAP mitigating strategy maintains the reactor within the envelope of conditions described by the licensee's existing shutdown margin capability. Furthermore, the licensee's shutdown margin capability retains conservatism 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 <u>FLEX Pumps and Water Supplies</u>

For Phase 2, the licensee's FIP describes two pumping methods and associated water supplies that will accomplish RPV, suppression pool, and SFP makeup to implement the FLEX plan. The preferred method is the FLEX seismic deep well pump. This pump is rated and tested to supply greater than 1000 gpm with a discharge pressure of at least 200 psig. According to the licensee, this capability is sufficient to supply the required RPV, suppression pool, and SFP makeup water needs for both units. A FLEX DG is deployed approximately 5.5 hours after ELAP event initiation in order to power the installed submersible pump in the deep well. The licensee's plan has provisions for a second "N+1" FLEX DG dedicated to the well pump function. A second water supply option is to deploy a trailer-mounted diesel engine-driven

FLEX pump to the vicinity of the circulating water discharge bay. The licensee's FIP indicates that if this option is used, one pump is capable of supplying both units. The licensee has two of these portable pumps in order to meet the "N+1" provision of NEI 12-06. Section 3.10 of this safety evaluation provides a discussion of the availability and robustness of the FLEX seismic deep well and circulating water discharge bay, which are used as the suction sources for the FLEX seismic deep well and FLEX diesel-driven pumps, respectively. In addition, Section 3.7.3.1 of this safety evaluation describes the primary and alternate connection points for RPV, suppression pool, and SFP injection using the FLEX seismic deep well pump or the FLEX diesel-driven pump.

To confirm the licensee's FIP description of the pumping capability of these two options, the staff reviewed hydraulic analysis QDC-0000-M-2097, "Pipe FLO Analysis of FLEX Strategy," Revision 0, as well as a pump curve for the seismic deep well pump. Based on this review, the staff was able to confirm that the two methods should be capable of providing the required capacity for RPV and SFP makeup simultaneously for both units. The pumps are also capable of providing simultaneous suppression pool and SFP makeup, as the licensee does not need to provide RPV and suppression pool makeup at the same time. During the onsite audit, the NRC staff conducted a walk down of the location of the pump and hose storage locations, the primary and alternate pathways, and location of the FLEX distribution header to confirm that these features were consistent with the hydraulic analysis. Based on the NRC staff's review of the FLEX pumping capabilities at Quad Cities, as described in the FIP and confirmed by the audit review, the NRC staff concludes that the FLEX seismic deep well pump and FLEX diesel-driven pump should perform as intended to support core cooling and RPV 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 postulated event. The electrical strategies described in the FIP are integrated for maintaining or restoring the critical functions of core cooling, containment, and SFP cooling. Any function-specific considerations for containment and SFP cooling are noted in Sections 3.3.4.4 and 3.4.4.4 of this safety evaluation.

According to the licensee's FIP, operators would declare an ELAP following a loss of offsite power, emergency diesel generators (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, the licensee relies on the safety-related Class 1E batteries (125 Vdc and 250 Vdc) to provide power to key instrumentation and applicable dc components. The Quad Cities Class 1E station batteries and associated dc distribution systems are located within robust structures designed to meet applicable design-basis external hazards. The batteries were manufactured by Exide Technologies. The 125 Vdc and 250 Vdc batteries are model GNB NCN-21 with a 1496 ampere-hours (AH) rating. The licensee's procedures direct 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 are expected to complete load shedding within 90 minutes from the onset of the event. In its FIP, the licensee stated that the station 125 Vdc batteries could cope for approximately 10 hours while the 250 Vdc batteries could cope for approximately 9 hours if the load shed is completed within 90 minutes.

During the audit process, the NRC staff reviewed the licensee's dc coping calculations QDC-8300-E-2100, "Unit 1(2) 125 VDC Battery Coping Calculation for Beyond Design Basis Flex Event," Revision 0, and QDC-8350-E-2101, "Unit 1(2) 250 VDC Battery Coping Calculation for Beyond Design Basis Flex Event," Revision 0, which evaluated the capability of the dc system to supply power to the required loads during the first phase of the licensee's FLEX mitigation strategy. The licensee's calculations identified the required loads and their associated ratings (ampere (A) and minimum required voltage) and the non-essential loads that would be shed within 90 minutes to ensure battery operation for the projected times. The staff also reviewed procedures QCOP-0050-01, "Unit 1 FLEX DC Load Shed," Revision 3, and QCOP-0050-02, "Unit 2 FLEX DC Load Shed," Revision 3, which provide guidance for load shedding the 250 Vdc and 125 Vdc batteries. Based on its review of the licensee's calculations and load shed procedures, the NRC staff found that the Class 1E 125 Vdc batteries should have sufficient capacity to supply power for at least 10 hours and the Class 1E 250 Vdc batteries should have sufficient capacity to supply power for at least 9 hours. Further, based on its review of the licensee's analyses and procedures, and the battery vendor's capacity and discharge rates for the Class 1E station batteries, the NRC staff finds that the Quad Cities 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 analyses.

The NEI White Paper, "EA-12-049 Mitigating Strategies Resolution of Extended Battery Duty Cycles Generic Concern," dated August 27, 2013 [Reference 63], provides guidance for calculating extended duty cycles of batteries (i.e., beyond 8 hours). By letter dated September 16, 2013 [Reference 64], this paper was endorsed by the NRC. 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 [Reference 65]. 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 licensee's Phase 2 strategy is to deploy two (one per unit) 480 Vac FLEX DGs to supply the 480 Vac buses, providing the ability to power the battery chargers and supply dc loads. The 480 Vac FLEX DGs are rated for 500 kilowatts (kW) and are sized to power the 125 and 250 Vdc battery chargers, RCIC components, ERVs, and vital instrumentation. The licensee plans to repower the required equipment in approximately 6 hours. The licensee's strategy allocates three 480 Vac DGs dedicated to this purpose. Since only two DGs are required to supply the power necessary to complete the licensee's FLEX strategies, the staff concludes that the licensee's plan for these FLEX DGs satisfies the "N+1" provision of NEI 12-06.

During the audit process, the NRC staff also reviewed licensee calculation QDC-7300-E-2099, "Unit 1(2) 480 VAC FLEX Diesel Generator and Cable Sizing for Beyond Design Basis FLEX Event," Revision 1, conceptual single line diagrams, and the separation and isolation of the FLEX DGs from the EDGs. Based on the NRC staff's review of QDC-7300-E-2099, the loading on each FLEX DG would be approximately 221 kW, which is well within the overall capacity for the FLEX DG.

The staff notes that the licensee took the FLEX cable lengths into consideration when sizing the FLEX DGs (i.e., ensured that the voltage drop did not result in violating the minimum required voltage required at the limiting component). Based on its review of the licensee's calculations, the NRC staff finds that two 480 Vac FLEX DGs are adequate to support the electrical loads required for the licensee's Phase 2 strategies. The NRC staff confirmed that licensee guidelines QCOP 0050-07, "FLEX Generator and Power Cable Deployment," Revision 3, and QCOP 0050-08, "FLEX Electrical Restoration," Revision 5, provide direction for staging and connecting the FLEX DGs to energize the electrical buses to supply required loads within the required timeframes.

For Phase 3, the licensee plans to continue the Phase 2 coping strategy with additional assistance provided from offsite equipment/resources. The offsite electrical equipment that will be provided by the NSRC includes four 1-megawatt (MW) 4160 Vac CTGs, two 1-MW 480 Vac CTGs, and distribution centers (including cables and connectors). Based on having a larger capacity than the Phase 2 FLEX DGs, the NRC staff finds that the 480 Vac CTGs being supplied from the NSRCs have sufficient capacity and capability to supply the required loads during Phase 3, if necessary.

Based on its review, the NRC staff finds that the Class 1E station batteries should have sufficient capacity to support the licensee's strategy, and that the FLEX DGs and NSRC supplied CTGs should have sufficient capacity and capability to supply the necessary loads during an ELAP event while maintaining adequate separation and isolation of the FLEX DGs and CTGs from the EDGs.

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 RPV 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

Guidance document NEI 12-06, Table 3-1 and Appendix C summarize an approach consisting of two separate capabilities for the SFP cooling strategies. This approach uses 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; and (2) makeup via connection to SFP cooling piping or other alternate location capable of exceeding the boil-off rate for the design basis heat load. However, in JLD-ISG-2012-01, Revision 1 [Reference 7], the NRC staff did not fully accept this approach, and added another requirement to either have the capability to provide spray flow to the SFP, or complete an SFP integrity evaluation which demonstrates that a seismic event would have a very low probability of inducing a crack in the SFP or its piping systems so that spray would not be needed to cool the spent fuel. The evaluation must use the reevaluated seismic hazard described in Section 3.5.1 below if it is higher than the site's current safe shutdown earthquake (SSE). 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 the Reactor Building.

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. This criterion is keeping 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 of this safety evaluation. According to the FIP, the licensee can provide the spray flow described in JLD-ISG-2012-01.

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. The licensee will monitor SFP water level using reliable SFP level instrumentation installed per Order EA-12-051. Hoses stored on the refuel floor in the Reactor Building will be deployed as a contingency to spray the pools or provide makeup water to maintain normal SFP level should the primary method (described below) be unavailable.

3.3.2 Phase 2

According to the licensee's FIP, a source of makeup water will need to be provided once the SFP reaches the boiling point. The source of water used will be the same as described for the RPV makeup strategy, either the seismic deep well pump or the FLEX diesel-driven pump. The primary method of makeup uses the Unit 1 RHR to fuel pool cooling return line as the primary path for SFP cooling. This method uses hose connected to the FLEX distribution header to supply the RHR to fuel pool cooling assist header, establishing a flow path to the connected SFPs. Alternately, the hoses from the distribution header can be routed directly to the SFP where direct makeup or SFP spray can be provided. For the spray method, two oscillating monitor nozzles are staged on the refuel floor that will allow 250 gpm of spray flow to be directed to each unit's SFP, if needed.

3.3.3 Phase 3

The FIP states that SFP cooling can be maintained indefinitely using the makeup strategies described in Phase 2 above. Additional pumps from the NSRC are available during Phase 3 for SFP cooling and provide additional defense-in-depth.

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) the SFP cooling system is intact, including attached piping.

During the audit process the staff reviewed the licensee's calculations regarding habitability in the SFP area to confirm the ability of the plant staff to deploy the necessary makeup provisions before habitability of the area becomes compromised. Specifically, the staff reviewed calculations QDC-1900-M-2079, "Fukushima – Spent Fuel Pool Time to Heat Up and Uncover Fuel," Revision 0, and 2014-02948, "Reactor Building Temperature Analysis Resulting from Extended Loss of AC Power," Revision 0. The FIP and supporting calculations indicate that boiling begins at approximately 13.5 hours during a normal, non-outage situation (partial core offload). The staff's review notes that the licensee's sequence of events timeline in the FIP indicates that SFP makeup will begin within 12 hours from event initiation.

As described in the licensee's FIP, the licensee's Phase 1 SFP cooling strategy does not require any specific operator actions. However, the licensee does establish a ventilation path to cope with temperature, humidity and condensation from evaporation and/or boiling of the SFP that will eventually occur. The operators are procedurally directed to open external building doors on the refueling and ground floors of the Reactor Building to establish ventilation and habitability of the SFP area.

The licensee's Phase 2 and Phase 3 SFP cooling strategy involves the use of the FLEX seismic deep well pump or FLEX diesel-driven pump (with suction from the circulating water discharge bay) to supply water to the SFP. The NRC staff's evaluation of the robustness and availability of the FLEX connection points is discussed in Section 3.7.3.1 of this safety evaluation. Furthermore, the NRC staff's evaluation of the FLEX seismic deep well and circulating water discharge bay is discussed in Section 3.10 of this safety evaluation.

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. The NRC staff's review of the SFP level instrumentation is discussed in Section 4 of this safety evaluation.

3.3.4.2 Thermal-Hydraulic Analyses

The licensee's FIP describes two cases that were evaluated in the SFP thermal-hydraulic analysis. The first case corresponds to a scenario where one unit has a full core offloaded into the SFP. In this case, the time to boil is 6.7 hours, the time to boil down to 12 feet above the fuel assemblies (assuming no makeup) is 31.5 hours, and the time to reach the top of fuel is 74.1 hours. For this heat load, a makeup rate of 92 gpm will match the boil-off rate. The second case corresponds to a partial core offload and would most closely reflect a scenario of both units at power (non-refueling outage condition). For the second case, the SFP decay heat load is lower and the time to boil is 13.5 hours, the time to reach 12 feet above the fuel is 62.8 hours, and the time to reach the top of fuel is 147.3 hours. For this heat load, the SFP makeup rate required would be 46 gpm. Based on the results of this analysis, the licensee determined that a SFP makeup flow rate of 100 gpm with provisions for a spray flow of 500 gpm (250 gpm for each SFP) would satisfy the provisions of NEI 12-06. The staff review concludes that the licensee has appropriately determined the projected SFP heat load and established makeup provisions that should mitigate the impacts of an ELAP event with respect to SFP cooling. Further, consistent with this guidance in NEI 12-06, Section 3.2.1.6, the NRC staff finds the licensee has considered the maximum design-basis SFP heat load.

3.3.4.3 FLEX Pumps and Water Supplies

As described in the FIP, the SFP cooling strategy relies on the FLEX pumps to provide SFP makeup during Phase 2. These pumps and their corresponding water supplies were described in Section 3.2.3.5 of this safety evaluation. The staff concludes that the licensee's plan is capable of providing SFP makeup (92 gpm) and spray (500 gpm) consistent with the provisions of NEI 12-06, Revision 2, as endorsed. Further, the NRC staff notes that the performance criteria of a FLEX pump supplied from an NSRC for Phase 3 would allow the NSRC pump to fulfill the SFP makeup function, if needed.

3.3.4.4 Electrical Analyses

The licensee's mitigating strategy for SFP cooling does not rely on electrical power, except for power to SFP level instrumentation and the FLEX DG powering the seismic deep well pump, if that option for makeup is utilized. The capability of the SFP level instrumentation is described in additional detail in Section 4 of this safety evaluation.

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

In order to develop the FLEX strategies, the industry guidance document, NEI 12-06, Table 3-1, provides 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 such approach is for a licensee to perform an analysis demonstrating that containment pressure control is not challenged. Quad Cities' two units are GE BWRs with Mark I containments.

To evaluate the containment parameters, the licensee's FIP describes a containment evaluation, QC-MISC-013, "MAAP Analysis to Support FLEX Initial Strategy," Revision 2, which was performed using the boundary conditions described in Section 2 of NEI 12-06. The calculation analyzed the strategy of removing heat from the suppression pool using the HCVS to mitigate the challenge to the primary containment pressure limit (PCPL) 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 56 psig and 281°F for greater than 72 hours. From its review of the FIP and the supporting evaluation, the NRC staff noted that required actions to maintain containment integrity and required instrumentation functions have been developed and are summarized below.

3.4.1 Phase 1

The licensee's FIP states that containment integrity is maintained by normal design features of the containment, such as the containment isolation valves, during Phase 1. In accordance with NEI 12-06, the containment isolation actions delineated in the station blackout (SBO) procedure are sufficient. The licensee will depressurize the RPV to 150-250 psig using the ERVs, which direct steam into the suppression pool. The licensee will utilize the HCVS to control containment pressure, as directed by the EOPs. The licensee's analysis assumes the containment is vented at 25 pounds per square inch absolute (psia) (approximately 10 psig). This action would keep containment parameters below the PCPL. According to the licensee, the HCVS requires no external power or motive air for 24 hours.

3.4.2 Phase 2

The strategy to maintain containment integrity for Phase 2 is to maintain containment pressure control and heat removal using the HCVS. Suppression pool water addition will be necessary to maintain level to replenish water lost through the containment vent. The licensee's FIP describes the suppression pool water level band (11-17 feet) that will be maintained, as well as the method of providing suppression pool makeup once one of the FLEX pumps described in Section 3.2.3.5 of this safety evaluation is deployed.

The licensee's FIP also states that the HCVS batteries can be recharged by restoring the battery charger feed from a FLEX DG. The motive power for cycling HCVS air-operated valves is from a bank of gas bottles located to allow replacement as needed.

3.4.3 Phase 3

The Phase 3 strategy continues the Phase 2 strategy. The Phase 3 equipment delivered from the NSRC will act as backup or as redundant equipment to the Phase 2 portable equipment. According to the licensee, sufficient resources will be available at the times required for Phase 3 implementation.

3.4.4 Staff Evaluations

3.4.4.1 Availability of Structures, Systems, and Components

Baseline assumptions in NEI 12-06 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

Primary Containment

Section 6.2.1.2 of the Quad Cities UFSAR, describes a GE Mark I primary containment. The primary containment system consists of a drywell, a pressure suppression chamber (alternatively referred to as the torus or wetwell), which is partially filled with water (referred to as the suppression pool), a vent system connecting the drywell and pressure suppression chamber water pool, isolation valves, and other service equipment.

The drywell is a steel pressure vessel composed of a spherical lower portion, a cylindrical middle portion, and a hemispherical top head, which houses the RPV, the reactor coolant recirculation system, and other branch connections to the reactor primary system. The drywell free volume is approximately 158,000 cubic feet. The drywell is designed for an internal pressure of 56 psig coincident with a maximum design temperature of 281°F, plus the dead, live, and seismic loads imposed on the shell.

The pressure suppression chamber is a steel pressure vessel, roughly in the shape of a torus, symmetrically encircling the drywell. The circular path around its major axis is formed by sixteen cylindrical segments, or bays. Alternate bays (eight in all) are connected to vent lines leading from the drywell. The pressure suppression pool contains approximately 115,000 cubic feet of water contained within the pressure suppression chamber. It serves both as a heat sink for postulated transients and accidents and as a source of water for the emergency core cooling system. The UFSAR Table 6.2-1, states the pressure suppression chamber internal design pressure is 56 psig, and the design temperature of the pressure suppression chamber is 281°F.

The primary containment and the HCVS valves are located within the Reactor Building, which is designed as a Seismic Category I structure. The staff notes that along with being a Seismic Category I structure, the Reactor Building is robust with respect to the postulated design-basis external events.

Hardened Containment Vent System

According to the licensee's FIP, the HCVS consists of the piping, valves, solenoid valves powered by a dedicated battery system, compressed argon purge gas, and compressed nitrogen motive gas to allow venting directly from primary containment to an elevated release point. It was designed to meet the requirements of Order EA-13-109 [Reference 51], but support for RCIC operation as part of the FLEX response was included in the design. To support FLEX, the HCVS meets the following design bases:

- The HCVS limits the long-term bulk temperature of the suppression pool to 240°F without spray operation. It does this through continuous venting of the suppression pool starting at 25 psia, which then responds as a saturated water system.
- The solenoid valves allow remote operation from the MCR. Local bypass valves allow operation of the system at the HCVS remote operating station located near the centerline of the mezzanine level of the turbine building.
- The HCVS is designed to perform its functions following a BDBEE, including tornados and seismic events.
- The HCVS is principally required to vent the steam flow equivalent of 1 percent of reactor power by EA-13-109. The ability to vent and limit temperature of the suppression pool was included in vent sizing during design and bounds the 1 percent flow requirement.

Based on the UFSAR and FIP descriptions, the staff concludes that 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 that should be monitored by repowering the appropriate instruments.

The licensee's FIP states that suppression pool level, containment pressure, and suppression pool temperature instruments remain available with the indication in the MCR prior to and after the dc load shedding that occurs during the ELAP response procedure implementation for up to 6 hours. Additional instruments for monitoring many of these parameters are restored after restoration of ac power during Phase 2. Alternate methods for obtaining the critical parameters locally are provided in an FSG.

Based on this information, the staff concludes that 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 containment evaluation utilized the MAAP computer code, version 4.0.5, to perform numeric computations of the fundamental thermodynamic equations that predict the heat up and pressurization of the containment atmosphere under ELAP conditions. According to the licensee's FIP, several sensitivity cases were performed to analyze methods of containment response using the FLEX strategy with multiple flow correction factors to assist in HCVS piping design.

The FIP describes the following initial conditions and time constraints that were used as MAAP input parameters:

- Initial suppression pool level is 14.05 feet.
- Initial suppression pool temperature is 92.5°F.
- Initial containment pressure is 0 psig to 1.2 psig (varies by location).
- Initial containment temperature is 92.5°F in the torus to 150°F in the drywell and pedestal.
- RCIC and HPCI are started manually at 5 minutes into the event. HPCI is secured whenever RPV water level indication shows greater than 40".
- RCIC operates with suction from the suppression pool and with no suppression pool cooling (i.e., contaminated condensate storage tanks (CCSTs) are not credited).

Specific manual actions or plant responses include the following:

- After HPCI is secured, operators commence an 80°F per hour cooldown using the ERVs.
- Once RPV cooldown is complete, RPV pressure is controlled between 150 and 250 psig.
- RCS leakage is 42 gpm. The leakage is modeled as a hole of fixed size that yields 42 gpm leakage at 1000 psig. At lower RPV pressure, the flow rate will decrease.
- When containment venting is credited, the vent is opened from the torus at a drywell pressure of 25 psia. This corresponds to a saturation temperature of 240°F and will maintain conditions below the PCPL.
- When external injection to the suppression pool is credited, the injection is initiated at the time the containment vent is opened.

The calculation (MAAP Case 6) shows that the peak drywell pressure reached is 25 psia (10.3 psig) when the HCVS vent is assumed to be opened and the peak drywell temperature was predicted to be 262°F. The peak suppression chamber pressure is calculated to be 25.2 psia psig (10.5 psig) with an airspace temperature of 249°F and a peak suppression pool temperature of 232°F. The maximum values calculated are below the UFSAR design parameters, so the staff concludes that the licensee has adequately demonstrated that there is sufficient margin before a containment limit would be reached.

3.4.4.3 <u>FLEX Pumps and Water Supplies</u>

These features are the same as what was described in Section 3.2.3.5 of this safety evaluation.

3.4.4.4 <u>Electrical Analyses</u>

The licensee's Phase 1 coping strategy is to monitor containment pressure and temperature using installed instrumentation and maintain containment capability using normal design features of the containment, such as the containment isolation valves and ERVs, as well as the HCVS. The licensee's strategy to repower instrumentation using the Class 1E station batteries is described in Section 3.2.3.6 of this safety evaluation and is adequate to ensure continued containment monitoring.

Each unit's HCVS system is powered from a common 125 Vdc shared battery that provides power to the HCVS solenoids. The HCVS battery is sized to provide a minimum of 24 hours of power to HCVS-related equipment. During the audit process, the NRC staff reviewed licensee calculation QDC-1600-E-2200, "125 VDC Battery Sizing Calculation for Hardened Containment Vent System for 24 Hour Duty Cycle," Revision 1, which evaluated the battery/battery charger sizing and device terminal voltages for the HCVS dc system. The results of the calculation showed that the HCVS battery, which is an Exide Technologies GNB MCX-9 battery (344 AH total), is adequately sized to supply power to the HCVS for at least 24 hours following an ELAP.

The licensee's Phase 2 coping strategy is to continue monitoring containment pressure and temperature using installed instrumentation and maintaining containment capability. The licensee's strategy to repower instrumentation and valves using the FLEX DGs is identical to what was described in Section 3.2.3.6 of this safety evaluation and is adequate to ensure continued containment monitoring and capability. The licensee also plans to recharge the HCVS battery utilizing the FLEX DGs. Based on its review of licensee calculation QDC-7300-E-2099, described previously, the NRC staff finds that the FLEX DGs can support the addition of the HCVS battery charger. The licensee would transition to Phase 2 prior to depleting the HCVS battery (i.e., within 24 hours). The staff confirmed that licensee guidelines QCOP 0050-08, "FLEX Electrical Restoration," Revision 5, and QCOP 1600-33, "Hardened Containment Vent System Lineup and Operation," Revision 1, provide guidance to energize the HCVS battery charger from the FLEX DGs.

The licensee's Phase 3 strategy is to continue its Phase 2 strategy throughout the event. The licensee will receive offsite resources and equipment, including CTGs, from an NSRC. Given the capacity of these CTGs, the NRC staff finds that it is reasonable to expect that the licensee could utilize these resources to supply power to the HCVS components to maintain the containment function indefinitely.

Based on its review, the NRC staff determined that the electrical equipment available onsite (e.g., Class 1E batteries, HCVS battery, and FLEX DGs) as supplemented with the equipment that will be supplied from an NSRC, should have sufficient capacity and capability to supply the required loads to maintain containment capability.

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 safety evaluation are consistent with the guidance in NEI 12-06 and the related NRC endorsement of NEI 12-06 in JLD-ISG-2012-01. Guidance document 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 [Reference 26], the NRC staff issued a Request for Information pursuant to Title 10 of the *Code of Federal Regulations* Part 50, Section 50.54(f) (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 52]. 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.

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 50]. The Commission provided guidance in an SRM to COMSECY-14-0037 [Reference 27]. In a letter to licensees dated September 1, 2015 [Reference 41], the NRC staff informed the licensees that the implementation of mitigation strategies should continue as described in licensee's OIPs, and that the NRC safety evaluations 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 have been 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 6]. The NRC staff endorsed Revision 2 of NEI 12-06 in JLD-ISG-2012-01, Revision 1 [Reference 7]. As documented by letter dated February 10, 2016 [Reference 55], the Quad Cities reevaluated seismic hazard was found by the NRC staff to be bounded by the existing design basis hazard in the frequency range of 1-10 Hertz, but was not bounded in portions of the frequency range above 10 Hertz. Based on those results, the licensee performed a high frequency evaluation [Reference 56] and prepared an MSA report [Reference 57]. The licensee's MSA report concluded that exceedance at frequencies greater than 10 Hertz qualified as a minimal exceedance and that the FLEX strategies could be implemented as designed and that no further seismic evaluations and or assessments were necessary. By letter dated June 15, 2016 [Reference 58], the NRC staff concluded that the licensee had appropriately addressed the reevaluated seismic hazard information stemming from the 50.54(f) letter.

For flooding, the NRC staff provided the licensee with an Interim Staff Response (ISR) letter detailing the reevaluated flooding hazards that were not bounded by the plant design basis [Reference 59], at Quad Cities. Specifically, the reevaluated hazard exceeded the existing plant design basis for the Local Intense Precipitation (LIP) and Combined Effects (riverine, dam failure, and waves) flood-causing mechanisms, and thus the licensee performed a flooding MSA [Reference 60]. In its MSA, the licensee stated that the FLEX design basis was developed using the reevaluated hazard information contained in the ISR letter as an input. Therefore, the licensee concluded that no further assessment of the impact of the reevaluated hazard on the FLEX strategies was required. By letter dated October 4, 2017 [Reference 61], the NRC staff concluded that the licensee's FLEX design basis incorporates the reevaluated hazards contained in the ISR letter.

The licensee developed its OIP for mitigation strategies by considering the guidance in NEI 12-06 and the site's design-basis hazards. This safety evaluation documents a determination based on the licensee's OIP, as updated in the 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, the SSE seismic criteria for the site is twenty-four hundredths of the acceleration due to gravity (0.24g) peak horizontal ground acceleration and 0.16g peak ground acceleration acting vertically. 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.

By referencing the design-basis seismic hazard in the FIP, the staff concludes that licensee has appropriately screened in this external hazard and identified the hazard levels to be evaluated. In addition, the staff notes that the licensee has assessed the reevaluated seismic hazard for impact on the FLEX strategies [Reference 57], and the NRC staff has concluded that the licensee has appropriately addressed this information [Reference 58].

3.5.2 Flooding

In its FIP, the licensee described that the current design basis for site flooding is based on a Mississippi River flood, which is described in UFSAR Section 3.4. This flood results in a water elevation that exceeds the site grade (594.5 feet mean sea level (MSL)) and could reach as high as 603 feet MSL. According to the UFSAR, for a flood up to the 603-foot MSL elevation, the plant can be safety shutdown and maintained in in a safe condition without the need for heat removal and related electrical power systems. The licensee's strategy for responding to the postulated river flooding event, combined with an ELAP, is based on the existing design-basis response and will use the projected flood warning time to preemptively shut down both units and place them in a configuration with the RPV heads removed and the refueling cavities flooded up to the level of the SFP. A portable pump, using the flood waters as a suction source, would then be used to provide makeup water to the combined SFP and reactor cavities to provide cooling for the duration of the flood event. The licensee's FIP states that the reevaluated combined flood event, which has a stillwater elevation of 600.9 feet, plus a wind wave component of 4.1 feet, for a total elevation of 605 feet MSL, will also be accommodated with this strategy.

Based on the FIP, MSA, and UFSAR descriptions, the staff concludes that the licensee has appropriately screened in this external hazard and identified the hazard levels to be evaluated. In addition, the staff notes that the licensee has assessed the reevaluated flooding hazard for impact on the FLEX strategies [Reference 60], and the NRC staff has concluded that the licensee has incorporated the reevaluated hazard levels into the FLEX design basis for flooding [Reference 61].

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 tornados.

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 tornados 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, Revision 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 tornados using the current licensing basis for tornados or Regulatory Guide 1.76, Revision 1.

In its FIP, regarding the determination of applicable extreme external hazards, the licensee stated that the site is located at 41° 43' 46" North latitude and 90° 18' 40.2" West longitude. In NEI 12-06, Figure 7-2, Recommended Tornado Design Wind Speeds for the 1E-6/year Probability Level indicates the site is in a region where the tornado design wind speed exceeds 130 mph. Therefore, the plant screens in for an assessment for high winds and tornados, including missiles produced by these events. Although the licensee did not address the impact of a hurricane in the FIP, the site is beyond the range of high winds from a hurricane per NEI 12-06, Figure 7-1. The NRC staff concludes that a hurricane hazard is not applicable and need not be addressed.

According to the Quad Cities UFSAR, Section 3.3.2.1, the tornado design parameters are: (1) a maximum tangential velocity of 300 mph; (2) a translational velocity of 60 mph; and (3) a pressure drop of 3 psi at the vortex within 3 seconds. In addition, according to the UFSAR, Section 3.5.4, two types of tornado missiles have been considered: (1) a utility pole 35 feet long with a diameter of 13 inches and a unit weight of 50 pounds per cubic foot having a velocity of 150 mph; and (2) a 1-ton mass with a velocity of 100 mph with a contact area of 25 square feet.

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 41° 43' 46" North latitude and 90° 18' 40.2" West longitude. The licensee's FIP acknowledges that the Quad Cities site would need to consider extreme snowfall, based on its location. In addition, the site is located within the region characterized by the EPRI as ice severity level 5 (NEI 12-06, Figure 8-2, Maximum Ice Storm Severity Maps). Consequently, the site is subject to severe icing conditions that could cause catastrophic damage to electrical transmission lines. The licensee concludes that the plant screens in for an assessment for snow, ice, and extreme cold hazard. According to the Quad Cities UFSAR, Section 2.3.2, the minimum temperature used for plant licensing was -26°F, based on nearby weather bureau data.

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 all sites are required to consider the impact of extreme high temperatures, as per NEI 12-06, Section 9.2. According to the Quad Cities UFSAR, Section 2.3.2, the maximum temperature used for plant licensing was 106°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

The licensee's storage strategy is based upon storing the "N" FLEX equipment in a single robust storage building that is designed to withstand all the postulated external events. This 60-foot by 90-foot structure is located in the northeast corner of the site's protected area. The "N+1" equipment is stored in a separate building located in the southeast corner of the employee parking lot. This building is not robust for all postulated hazards. According to the licensee's FIP, the storage configuration meets the provisions of NEI 12-06, Revision 2. Below are additional details on how FLEX equipment is protected from each of the applicable external hazards.

3.6.1.1 Seismic

Since the robust FLEX Storage Building is designed to withstand the seismic BDBEE hazard for the site, "N" sets of FLEX equipment are protected from this hazard. The licensee's FIP further states that the large, portable FLEX equipment such as pumps, generators, hose trailers with well pump motor starters, vehicles, and satellite communications trailers stored in the building are secured with tie-down straps to floor anchors integrated into the floor slab to protect them during a seismic event. Revision 2 of NEI 12-06, Section 5.3.1.1, describes protection from seismically-induced challenges and states that FLEX equipment should be stored such that no one external event can reasonably fail the site FLEX capability ("N").

Based on the FIP description, the staff concludes that the licensee's storage plan meets the provisions of NEI 12-06, Revision 2, and therefore provides reasonable protection from this postulated BDBEE.

3.6.1.2 Flooding

For a flooding event, the licensee's strategy depends on the flood-causing mechanism. For a Mississippi River flood, the licensee anticipates using the projected flood warning time to prepare the site response. According to the licensee's fifth six-month update, UFSAR Section 3.4.1.1 provides a summary of the mitigation efforts for this event. According to the UFSAR, the river level is projected several weeks in advance. The licensee's update specifies that a 96-hour timeframe is used to prepare the site response. In addition to shutting down the reactors and flooding the reactor cavities, the UFSAR states that the independently powered portable pumping equipment will be set up above the projected flood elevation to provide the 200 gpm of makeup flow that is required to compensate for evaporative cooling loss. According to NEI 12-06, Revision 2, FLEX equipment can be stored below flood level if time is available and plant procedures/guidance address the needed actions to relocate the equipment. Based on the UFSAR description, supplemented by the licensee's FIP and fifth six-month update, the NRC concludes that the licensee's storage plan meets the provisions of NEI 12-06, Revision 2, and therefore provides reasonable protection from this postulated BDBEE.

For the LIP event, the licensee's FIP states that the robust storage building is elevated approximately 1 foot above grade and removable LIP barriers are installed for the equipment doors. Further, the FIP states that the personnel doors are designed to withstand an elevated water condition. According to NEI 12-06, Revision 2, FLEX equipment can be stored in a structure designed to protect the equipment from the flood. Based on the FIP description the NRC staff concludes that the licensee's storage plan for the LIP scenario meets the provisions of NEI 12-06, Revision 2, and therefore provides reasonable protection from this postulated BDBEE.

3.6.1.3 High Winds

Since the robust FLEX Storage Building is designed to withstand the tornado wind and tornado missile BDBEE hazard for the site, "N" sets of FLEX equipment are protected from this hazard. Revision 2 of NEI 12-06, Section 7.3.1.1, describes protection from high wind-induced challenges and states that FLEX equipment should be stored such that no one external event can reasonably fail the site FLEX capability ("N"). Further, Section 7.3.1.2 of NEI 12-06, Revision 2, provides examples of acceptable high wind storage configurations. One of these is two sets of equipment (N) in a structure(s) that meets the plant's design basis for high wind hazards and one set (+1) stored in a location not protected for a high wind hazard. The licensee's FIP description corresponds to this example. Thus, the staff concludes that the licensee's storage plan for the high wind scenario meets the provisions of NEI 12-06, Revision 2, and provides reasonable protection from this postulated BDBEE.

3.6.1.4 Snow, Ice, Extreme Cold, and Extreme Heat

According to the licensee's FIP, the robust FLEX Storage Building is designed to withstand the effects of the applicable BDBEE hazards, including snow, ice, extreme cold, and extreme heat. The FIP also states that the equipment used to support the FLEX strategies is stored either inside the plant or in the FLEX Storage Building which is protected from snow, ice, and extreme cold in accordance with NEI 12-06, and is temperature controlled. During the audit process the staff reviewed Engineering Change (EC) 398181, "FLEX Storage Building," Revision 2, and confirmed that the building heating and ventilation systems will maintain the building temperature between 40°F and 105°F. During the audit process the staff also confirmed that the licensee's commercial "N+1" storage building contains provisions for temperature control using unit heaters and ventilation provisions by reviewing EC 400708, "FLEX+1 Commercial Storage Building," Revision 0. The staff also confirmed that the "N+1" building contains provisions for snow loads appropriate for the Quad Cities area. The staff concludes that the licensee's storage plan provides reasonable protection from snow, ice, extreme cold, and extreme heat conditions.

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, and should adequately address the requirements of the order.

3.6.2 Availability of FLEX Equipment

Section 3.2.2.16 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.

To supply makeup water in Phase 2, the licensee's primary strategy is to provide flow to both units from a seismic well pump. The licensee's strategy does not incorporate an "N+1" seismic well pump, nor is the seismic well pump protected from tornado winds and associated missiles. However, the licensee has the capability to deploy a FLEX diesel-driven pump taking a suction from the circulating water discharge bay to provide a backup capability to the seismic well pump. For this provision, the licensee has a total of two pumps available, with one pump able to provide the necessary supply both units. Overall, the staff concludes that the licensee's water supply strategy satisfies the "N+1" provision of NEI 12-06. To accommodate periods of unavailability of the seismic well pump, the licensee has proposed a related alternative that is described in Section 3.14.1 of this safety evaluation.

The licensee's strategy for electrical supply is to deploy one FLEX DG per unit to supply the necessary in-plant loads and a third FLEX DG to supply the seismic well pump. The licensee's plan stipulates that there will be five FLEX DGs total. This capability would thus incorporate a spare FLEX DG for both the in-plant loads and a separate spare for the seismic well pump. The staff concludes that this capability meets the "N+1" provision of NEI 12-06 for the FLEX DGs.

As described in its fifth six-month update, the licensee plans to follow the white paper guidance for spare hoses and cables that was proposed [Reference 44] by the NEI and later endorsed [Reference 45] by the NRC. The licensee's FIP stipulates that this is not an alternative to NEI 12-06, Revision 2 as the white paper, as endorsed, was incorporated into that revision of NEI 12-06. Based on the licensee following the guidance of the NEI white paper, as endorsed and incorporated into NEI 12-06, Revision 2, the staff concludes that this meets the "N+1" provision regarding spare hoses and cables.

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 and core cooling, SFP makeup, and maintaining containment consistent with the "N+1" recommendation in Section 3.2.2 of NEI 12-06.

3.7 Planned Deployment of FLEX Equipment

To support the licensee's electrical strategy, two FLEX DGs are deployed from the robust FLEX Storage Building. Depending on the water strategy that is chosen, the licensee will have to deploy at least one of the following: (1) a FLEX DG to power the seismic well pump; or (2) a diesel engine-driven FLEX pump to the discharge canal. The licensee will also have to deploy the associated hoses and cables for the equipment being used.

3.7.1 Means of Deployment

According to the licensee's FIP, equipment being transported for the Phase 2 strategies will be towed by either a FLEX F-750 truck or a tractor, both of which are stored on-site. The licensee's strategy is designed to minimize the need for debris removal through short haul paths both for the deep well water source and the other FLEX DG deployment locations, as well the capability for multiple deployment paths. The FIP states that debris removal equipment includes the plow on the FLEX truck, a 4-wheel drive tractor with a front bucket, and tools for cutting through debris. Also, there is additional hose and cable for manual deployment across debris if the capabilities of the truck and the tractor are exceeded. Debris removal equipment (primarily the tractor) is stored inside the robust FLEX Storage Building for protection from the applicable BDBEEs such that the equipment will be functional and deployable to clear obstructions from the paths between the equipment's storage and deployment locations. Deployment of the debris removal equipment from the robust FLEX Storage Building is not dependent on electrical power. Based on the FIP description, the staff concludes that the licensee's means of deployment meets the provisions of NEI 12-06 regarding protection, debris removal capability, and accessibility.

3.7.2 Deployment Strategies

The licensee has pre-determined staging locations and deployment routes for the major pieces of FLEX equipment. The licensee's plan recognizes that snow/ice removal may be required to deploy FLEX equipment and the FIP states that the FLEX deployment paths have been incorporated into the site snow removal process. According to the licensee's FIP, a liquefaction evaluation concluded that there is a potential of subgrade liquefaction at intermittent depths below grade during the SSE. The potential resulting SSE-induced ground settlements are less than 1 inch along the deployment paths and are a maximum 5 inches at the robust FLEX Storage Building. The FIP states that this potential was incorporated into the FLEX Storage Building design and the licensee's evaluation concluded that this settlement would not affect the equipment deployment.

The licensee's FIP also states that a site procedure periodically inspects external and internal deployment paths that, if blocked, could hamper the deployment of equipment in response to an ELAP event. Included in this procedure are actions to be taken when the surveillance is found unsatisfactory.

For a flooding event on the Mississippi River, the licensee would pre-deploy the necessary equipment.

Based on the licensee's FIP description, the NRC staff concludes that the licensee's plan includes deployment strategies that account for the potential BDBEE's and thus meets the provisions of NEI 12-06.

3.7.3 Connection Points

3.7.3.1 Mechanical Connection Points

RPV and Suppression Pool Makeup

Sections 3.2, 3.3.2.1, 3.3.2.2, and 7.2 of the licensee's FIP describe the primary and alternate RPV and suppression pool makeup connection points. The licensee's water strategy for Phases 2 and 3 includes preferred (seismic well) and alternate (circulating water bay) sources. Both sources supply water to a distribution header that is created from standard 5-inch fire hose fittings. For the preferred (seismic well) source, the distribution header is located either inside the 1/2 Unit Trackway or inside the Unit 1 or 2 Reactor Building. From the distribution header, hoses can be run to either the Unit 1/Unit 2 condensate transfer fill system to RHR connection or the Unit 1/Unit 2 "A" drywell spray header connection. For the alternate (circulating water bay with diesel-driven FLEX pump) source, the hose deployment from the pump discharge would route to the distribution header located either at the 1/2 Unit Trackway, similar to the location used for the well pump source, or through the Service Building and into the Reactor Building. From the distribution header locations, the hose routing would be similar to that used for the preferred source. In both cases, the connections are in structures that are protected from all applicable external hazards.

SFP Cooling

For SFP makeup, the licensee's strategy uses the same distribution headers as were described for RPV and suppression pool makeup. From the distribution headers hoses are routed to either the RHR to fuel pool cooling assist header, or directly to the SFPs, to provide water to makeup SFP level. If spray is required, the hoses that route directly to the SFPs can be connected to portable monitor nozzles staged on the refuel floor to spray into each SFP. The FLEX connections for SFP cooling are located inside the Reactor Building, which is robust against all applicable external hazards.

3.7.3.2 Electrical Connection Points

During Phase 2, the licensee's strategy to re-power essential equipment requires deployment of two 480 Vac FLEX DGs. The primary staging area for the DGs is outside the Reactor Building trackway. The alternate staging area is the Unit 2 Turbine Building trackway. Connection cables can be deployed from either location to the 480 Vac Division 1 or 2 buses to restore power to support the FLEX strategy. Connection cables are stored at two locations in the Reactor Building and one location in the Turbine Building. The cable stored at these three different storage locations provides proximity to the deployment paths and sufficient cable to meet the "N+1" provision of NEI 12-06. Connections to the 480 Vac system are made via pigtails with quick disconnect type connectors installed at the tie breaker outputs for Buses 18, 19, 28 and 29. These buses are in the Turbine Building.

The licensee's UFSAR, Section 3.2.1, describes the Reactor Building's safety classification as Class I. Section 3.5.4 of the UFSAR describes the capability of the Reactor Building to resist high wind (tornado) missile loads, and Section 3.7 describes the seismic capability of the structure. Based on the UFSAR description, the staff concludes that the Reactor Building is robust in accordance with the provisions of NEI 12-06. As described in Sections 3.8.4 and 3.8.6 of the UFSAR, the Turbine Building is not specifically classified as a Class I structure. However, the UFSAR, Section 3.3.1.1.4, describes how the Turbine Building is similar in design to the Reactor Building in terms of its wind load resistance. The UFSAR, Section 3.3.1.1.2, describes the missile protection afforded to the 480 Vac switchgear area of the Turbine Building from a postulated chimney failure. In addition, UFSAR Sections 3.7.1 and 3.7.2 describe how the seismic modeling of the Turbine Building was coupled with the Reactor Building to evaluate the connected buildings' interaction effects. Based on the UFSAR description, confirmed by the site audit walk down, the staff concludes that the portions of the Turbine Building supporting the licensee's electrical FLEX strategy provide reasonable protection from the postulated external events.

The licensee's electrical deployment paths are depicted in Figures 10 and 11 of the FIP. The primary path requires cables to be deployed from two locations: 250-foot cable reels staged south of the Reactor Building 3rd floor interlock doors and 250-foot cable reels staged by the Unit 2 Turbine Building main floor equipment hatch. This path uses conduit sleeves on the north face of the Unit 2 Turbine Building as a building entry point. The power cables are deployed from Buses 18/19 and 28/29 around the east side of the Unit 2 Turbine Building main floor to the equipment hatch and then lowered to the ground level for connection to the FLEX DGs. The alternate electrical strategy requires cables to be deployed from two locations: 250-foot cable reels staged south of the Reactor Building 3rd floor interlock doors and 250-foot cables reels staged in the Reactor Building 3rd floor by the control rod drive repair room. The alternate path uses the Reactor Building equipment or personnel interlock doors as a building entry point. The power cables would be deployed from Buses 18/19 and 28/29 around the south side of Unit 1 to the equipment hatch and then lowered to the ground level for connection to the FLEX DGs. For each strategy, the cable segments would be conjoined via their male/female connectors to form a 500-foot cable run. This cable is then connected to the 100-foot segment that is staged with each FLEX DG for a total circuit length of 600 feet.

During the audit process, the NRC staff confirmed that licensee guideline QCOP 0050-07 provides direction for staging and connecting the FLEX DGs to energize the electrical buses to supply required loads within the required timeframes. In addition to the color-coded cables and connections, the NRC staff confirmed that the licensee verified proper phase rotation of the Phase 2 FLEX DGs through testing.

For Phase 3, the licensee plans to continue the Phase 2 coping strategy with additional assistance provided from offsite equipment/resources. The offsite electrical equipment that will be provided by the NSRC includes four 1-MW 4160 Vac CTGs, two 1-MW 480 Vac CTGs, and distribution centers (including cables and connectors). The licensee would stage the 480 Vac CTGs near the Phase 2 FLEX DGs and utilize the same connections if necessary. The staff reviewed guideline QCOP-0050-16, "FLEX National Safer Response Center Interface," Revision 3, and confirmed that it provides direction for staging and connecting FLEX CTGs to energize the electrical buses to supply required loads. The staff also confirmed that QCOP-0050-16 includes a step to assure proper phase rotation of the NSRC-supplied CTGs using phase rotation instrumentation checks prior to energizing any rotation sensitive equipment such as pump motors or MOVs.

3.7.4 Accessibility and Lighting

According to the licensee's FIP, the installed station lighting would not be initially available. It is restored in Phase 2, as the FLEX DG loading allows. Emergency lighting packs are installed throughout the plant to provide general area lighting to assist in installation of FLEX response power cables and hoses required for Phase 2 equipment connections. While these lighting packs were not installed with specific seismic considerations, and are therefore not credited during the response measures, they are likely to be available following the initiating event. According to the licensee, walk-downs of the travel paths and connection points were reviewed, and the illumination provided by the light packs will provide sufficient lighting. In addition, licensee procedures will also provide direction for the use of the Appendix R tools which include hands-free flashlights. Equipment operators are provided hands-free hard hat lights as part of their normal complement of equipment for job performance, and there are staged flashlights in the operations ready room. In addition, bar lights are stored in the robust FLEX Storage Building and thus would be available following a BDBEE. Based on the FIP description the staff concludes that the licensee has incorporated lighting provisions into the FLEX plan consistent with the provisions of NEI 12-06, Section 3.2.2.

3.7.5 Access to Protected and Vital Areas

According to the licensee's FIP, operators responding to the event possess keys that will allow access through security doors. Electrically operated gates on the site access roads and on the footpath leading to the FLEX Storage Building can be manually opened by a security officer.

Based on the FIP description, the staff concludes that 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

Section 4.1 of the FIP describes the licensee's fueling strategy. According to the licensee, there are three EDG Fuel Oil Storage Tanks (FOSTs) at Quad Cities that each have approximately 12,000 gallons of usable fuel, as well as three associated EDG day tanks with approximately 592 gallons each. Additional non-robust diesel fuel that may be available onsite includes the SBO main storage tank with about 15,000 gallons, two SBO day tanks with 530 gallons each, two fire diesel day tanks with 530 gallons each, and a security diesel fuel tank with 400 gallons. These additional diesel fuel sources are not protected from tornado or seismic events; however, the licensee indicated that these fuel sources could be used if they are available. The licensee's FIP also describes four different procedurally-driven mechanisms involving both installed and portable pumps to distribute the diesel fuel oil to the FLEX equipment throughout the ELAP event. The licensee analyzed that the on-site available fuel oil will be able to support operation of FLEX equipment for 25 days before off-site fuel oil will be needed. The licensee also indicated in its FIP that the fuel oil of diesel engine-driven FLEX equipment will be maintained as part of the site Preventative Maintenance (PM) program.

The NRC staff conducted an onsite audit walk down of the three underground EDG and day tank locations to confirm the accessibility of fuel oil during the ELAP event. The NRC staff also reviewed the applicable FSGs to confirm that the FLEX equipment specified is consistent with the FIP description. Based on the FIP description, confirmed by the audit review, the NRC staff finds that the overall FLEX refueling strategy includes provisions that should provide sufficient availability of the fuel oil and the accessibility to refuel the FLEX equipment during an ELAP event.

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 Quad Cities 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. (Framatome) 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 46], 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 staff subsequently updated the staff assessment of the NSRCs to account for provisions relating to certain non-nuclear emergencies [Reference 62].

During the audit process, the NRC staff noted that the licensee's SAFER response plan includes: (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 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. Primary Staging Area "C" and an Alternate (Area "D"), if available, 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. Staging Area "C" is the Whiteside County Airport, located east of the Quad Cities site (travel distance approximately 40 miles, 32 miles direct path). Staging Area "D" is the Quad Cities International Airport, located southwest of the Quad Cities site (travel distance approximately 31 miles, 21 miles direct path). Staging Area "B" is the supplemental work force parking lot. Staging Area "A" corresponds to the various deployment locations for the FLEX equipment near the applicable plant buildings. Use of helicopters to transport equipment from Staging Area "C" to Staging Area "B" is provided for within the licensee's SAFER plan.

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, ventilation that provides cooling to occupied areas and areas containing required equipment will be lost. Per the guidance given in NEI 12-06, FLEX strategies must be capable of execution under the adverse conditions (unavailability of installed plant lighting, ventilation, etc.) expected following a BDBEE resulting in an ELAP.

The primary concern regarding ventilation is the heat buildup that occurs with the loss of forced ventilation in areas that continue to have heat loads. The licensee performed loss of ventilation analyses to quantify the temperatures expected in specific areas of the plant related to FLEX implementation to ensure the environmental conditions remain acceptable for equipment operation and for personnel habitability or accessibility regarding the FLEX strategy.

According to the licensee's FIP, the key equipment areas identified for execution of the FLEX strategy activities are the MCR/auxiliary electrical room (AER), RCIC pump room, and battery rooms. The licensee evaluated these areas to determine the temperature profiles following the postulated event. The results of the licensee's room heat-up evaluations in conjunction with the licensee's strategies have concluded that temperatures should remain within acceptable limits.

Main Control Room/Auxiliary Electrical Room

In its FIP, the licensee stated that Quad Cities is using 120°F as the upper limit for the MCR based on the site's current licensing basis for compliance with the SBO rule. To maintain the MCR below this limit, Quad Cities will employ a "Toolbox Approach" for coping with extreme temperatures during FLEX implementation. Examples of acceptable toolbox actions to cope with extreme temperatures are:

- Opening doors when room temperatures become elevated;
- Rotation of personnel;
- Use of ice vests, etc. when tasks are in high heat and humidity;
- Utilizing small fans for air movement;
- Warming/cooling in available vehicles; and
- Utilizing firefighting turn-out gear to cope with extreme low temperatures.

During the audit process, the staff reviewed Procedure QCOP 0050-11, "FLEX Control Room Ventilation," Revision 1, to confirm that it provides the primary means to ventilate the room, which will direct operators to open doors and panels and to utilize small generators, portable fans, and ductwork to maintain MCR and AER temperatures less than 120°F.

Based on the FIP description, the NRC staff concludes that the licensee's plan should maintain adequate MCR temperatures by following the toolbox actions. Based on MCR temperatures 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 [Reference 66], for electronic equipment to be able to survive indefinitely), the NRC staff expects that the equipment in the MCR and AER should not be adversely impacted by the loss of ventilation as a result of an ELAP event.

RCIC Pump Room

According to the licensee's FIP, the RCIC pump rooms could reach 150°F in approximately 9 hours, but will not reach 180°F for the 72 hours that were analyzed. The FIP also states that the 9-hour timeframe will allow sufficient time for deployment of the Phase 2 FLEX equipment, such that RCIC would not be needed for core cooling. To confirm the licensee's FIP description, the staff reviewed licensee calculation 2014-02948, "Reactor Building Temperature Analysis Resulting from Extended Loss of AC Power," Revision 0, during the audit process. This calculation modeled, in part, the temperature transient response in the RCIC pump room for 72 hours during ELAP conditions and determined what recovery actions (if any) would be required to maintain operability of the equipment in the room. The initial room temperature was assumed to be 104°F and the calculation models the opening of various Reactor Building doors within 3 hours from the onset of an ELAP event. The staff confirmed that the licensee's calculation shows that the RCIC pump room never reaches 180°F for the 72 hours analyzed.

The licensee's FIP also indicates that there is a FLEX strategy in place for cooling the RCIC room, which involves restoring the existing room cooler. Power to the room cooler fans will be provided once the FLEX DG is connected. Cooling water to the room cooler can be provided once the chosen Phase 2 FLEX pump is placed in service. The licensee has installed connections to the emergency core cooling system room cooler supply lines, which feeds the RCIC room cooler. Through these connections, the pump can provide cooling water to the room cooler. The licensee's FIP indicates that a FLEX procedure provides the contingency actions to provide FLEX water flow the RCIC room coolers.

Based on the above, the NRC staff finds that the licensee's strategy should maintain the temperature of the RCIC pump room below the functional limit of the equipment in the RCIC pump room for at least 72 hours. Therefore, the NRC staff finds that the RCIC systems on each unit should not be adversely impacted by the loss of ventilation as a result of an ELAP event.

Battery Rooms

According to its FIP, the licensee evaluated temperatures in the battery rooms and battery charger rooms for the ELAP event. Since the initial results showed that excessive temperatures were possible for the summer cases, the licensee modeled compensatory actions of opening doors and deploying fans to ventilate this area of the plant. According to the licensee's FIP, these compensatory actions have been added to a station procedure. During the audit process the staff reviewed the licensee's supporting calculation 2014-05860, "Battery and Charger Room Temperature Response for FLEX Evaluation," Revision 0, which calculated the temperature response of the Unit 1 and 2 battery rooms, the battery charger rooms, and the dc panel rooms. During the audit process, the staff also reviewed procedure QCOP 0050-10, "FLEX Battery Room Ventilation," Revision 2, which directs operators to open doors and deploy portable fans to draw air from outside the turbine building to cool the battery and battery charger rooms. Additionally, the staff observed that for high external temperatures, the procedure contains steps for the installation of supplemental electrical fans for the battery and charger rooms powered by portable generators.

Based on the FIP description, as confirmed by the audit review, the NRC staff finds that the licensee's ventilation strategy (establishing ventilation and opening doors) should be able to provide the ventilation necessary for the necessary FLEX electrical equipment in this area to support the overall mitigation strategy. Therefore, the NRC staff finds that the electrical equipment located in the battery and battery charger rooms should not be adversely impacted by the loss of ventilation as a result of an ELAP event.

Switchgear in Turbine Building

During the audit process, the NRC staff reviewed licensee analysis EC-EVAL 398588 (no title), Revision 0, to confirm that the switchgear relied upon as part of the Quad Cities mitigation strategy will not be adversely affected by increase temperature as a result of loss of ventilation. The switchgear necessary to implement FLEX strategies at Quad Cities is in the Turbine Building. The licensee's evaluation showed that peak temperatures in the areas containing the required switchgear were expected to remain less than 120°F for at least 72 hours.

For areas of the Turbine Building containing the required switchgear that must remain below 120°F (the temperature limit for electronic equipment to be able to survive indefinitely, identified in NUMARC-87-00), the NRC staff expects that the required switchgear in the Turbine Building should not be adversely impacted by the loss of ventilation as a result of an ELAP event.

Containment Areas

During the audit process, the NRC staff reviewed the licensee's analysis QC-MISC-013, "MAAP Analysis to Support FLEX Initial Strategy," Revision 2, to determine the containment temperature profile during an ELAP. Per Case 6 on page 46 of the MAAP analysis, containment temperature will peak at 262°F. According to the Quad Cities environmental qualification program, the emergency core cooling system equipment is tested/analyzed to function at temperatures up to 338°F for high energy line breaks and 294°F for loss of coolant accidents.

A limited number of instruments in containment used in the FLEX strategy are required to remain operable for post-accident monitoring. The staff audit review noted that the drywell temperatures peak below the applicable design-basis environmental qualification limits. The staff also reviewed the MAAP analysis results and compared them to the station's environmental qualification profile. Based on that comparison, the staff concludes that the qualified components in the drywell, such as the ERVs/SRVs and instrumentation, should remain available during an ELAP event.

The NRC staff also notes that the licensee 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 would utilize these resources to help reduce or maintain temperatures within containment to ensure that required electrical equipment survives indefinitely, if necessary.

Based on its review of the essential station equipment required to support the FLEX mitigation strategy, which are primarily located in the MCR and AER, RCIC pump rooms, battery and battery charger rooms, Turbine Building (areas containing the required switchgear), 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 the postulated event.

3.9.1.2 Loss of Heating

The licensee stated in its FIP that heat tracing is not required for FLEX strategies due to the equipment being stored either inside the plant or the FLEX Storage Buildings, which are protected from snow, ice, and extreme cold in accordance with NEI 12-06, and are temperature controlled. The licensee also indicated that the FLEX connection points for RPV and SFP makeup are all located inside structures which are temperature controlled. The licensee's FIP also indicates that foul weather gear is available to support outside deployment activities. Based on the FIP description, the NRC staff finds that the equipment used for FLEX strategies should perform their required functions despite a loss of normal heating during an ELAP event.

During the audit process, the staff noted that the Quad Cities Class 1E station battery rooms are located inside robust structures and will not be directly exposed to extreme low temperatures. At the onset of the event, these 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, the concrete walls isolating the rooms from the outdoors, and the lack of forced outdoor air ventilation during the early phases of an ELAP event. Based on the above, the NRC staff finds that Quad Cities Class 1E station batteries should perform their required functions despite a loss of normal heating during the postulated ELAP event.

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 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 licensee's FIP states that battery room ventilation is established to prevent hydrogen buildup. During the audit process, the staff reviewed the licensee's hydrogen generation analysis, QC-1ET-E-001, "Battery Room Minimum Airflow Requirements," Revision 0, and procedure QCOP 0050-10, which provides guidance for establishing required ventilation to maintain hydrogen concentration below combustible limits in the Class 1E battery rooms. The guidance directs operators to establish battery room ventilation after the battery chargers have been energized by re-energizing the normal exhaust fans or, alternatively, to utilize small generators, portable fans, and ductwork and opening various doors. The audit review concluded that the minimum airflow necessary should be provided by the licensee's procedure actions.

Based on the FIP description, as confirmed by the audit review, the NRC staff finds that hydrogen accumulation in the Quad Cities Class 1E battery rooms should not reach the combustibility limit for hydrogen (4 percent) during an ELAP event.

3.9.2 Personnel Habitability

3.9.2.1 Main Control Room

As described in Section 3.9.1.1 of this safety evaluation, the licensee will be employing a "Toolbox Approach" for coping with extreme temperatures during FLEX implementation. This strategy will maintain the MCR temperature below 120°F, which the licensee states is the upper limit for the MCR based on the site's current design and licensing basis for compliance with the SBO rule. In addition, the FIP states that procedure QCOP 0050-11, "FLEX Control Room Ventilation," provides the primary means to ventilate the room, by opening doors and use of portable fans.

The NRC staff notes that even though Quad Cities uses an upper habitability limit that is greater than the guidance in NUMARC 87-00, the NRC staff finds it reasonable that operators could safely utilize the MCR during an ELAP event using the "Toolbox Approach." The NRC staff concludes that with the limited stay time, the use of ice vests, and the utilization of small fans for air movement, the elevated temperatures should not impede operators from performing the necessary actions in the MCR to support the FLEX mitigation strategy during an ELAP event.

3.9.2.2 Spent Fuel Pool Area

According to the licensee's FIP, ventilation for the refuel floor is provided by opening external building doors on the refueling and ground floors of the Reactor Building thereby allowing natural convection within the building to support personnel habitability for response actions. The licensee's FIP also states that several site procedures have elements that support habitability for personnel performing response actions. The FIP states that the licensee's procedures identify the need to promptly complete the local connection and hose routing actions regarding SFP makeup before the environmental conditions in the area degrade. During the audit process, the NRC staff reviewed the applicable procedures to confirm the FIP description and concludes that the licensee has established an adequate ventilation strategy for this area.

3.9.2.3 Other Plant Areas

The licensee's FIP describes the other strategy elements that could be impacted by the Reactor Building environment. The licensee notes that the actions involving connections supporting the RPV makeup and containment capability functions are accomplished within 6 hours of event initiation such that they are completed before the environmental conditions degrade significantly.

The licensee's FIP also notes that actions required later in the event in all buildings are subject to applicable site and fleet procedures, including but not limited to, SA-AA-111, "Heat Stress Control," to mitigate the risks of working in a hot environment. Following a BDBEE at Quad Cities, a "Toolbox Approach" will be used to determine operator stay times and need for personnel protection such as ice vests.

Based on the FIP description, the staff concludes that elevated temperatures should not impede operators from performing the necessary actions in other plant areas to support the FLEX mitigation strategy during an ELAP event.

3.9.3 Conclusions

The NRC staff concludes that the licensee has developed guidance that, if implemented appropriately, should maintain or restore equipment and personnel habitability conditions 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.

3.10 Water Sources

3.10.1 RPV Makeup

Phase 1

As described in the FIP, the CCSTs are the normal suction source for the RCIC pumps. However, they are not robust for all potential external events and thus are not credited in the licensee's supporting analysis. If available, they could be used and would have the benefit of providing a cooler suction source for RCIC, as compared to the suppression pool. The suppression pool provides makeup water to the RPV through the RCIC system after ELAP initiation. The suppression pool is described as near reactor quality water. It is in the primary containment structure and is fully protected from all applicable external events.

Phase 2

During Phase 2, the FLEX seismic deep well pump, which is located in the deep well east of the Reactor Building, will be powered by a FLEX DG to provide raw, non-demineralized well water for RPV, suppression pool, and SFP makeup, as required. A strainer screen at the pump suction keeps large particles from entering the pump and discharge path. This source of water should be available for all external events except high winds and flooding. The alternate water source for RPV, suppression pool and SFP makeup is provided by the circulating water discharge bay. A FLEX diesel-driven pump is deployed on a ramp at the discharge bay and lightweight suction hoses and floating suction strainer would be deployed. This source of water is connected to the Mississippi River and should be available to provide raw, non-demineralized water for high-wind events and provide a backup to the seismic well for other postulated conditions and events.

Phase 3

For Phase 3, RPV makeup sources are the same as for the Phase 2 strategy.

3.10.2 Suppression Pool Makeup

Section 9.1 of the licensee's FIP discusses the need to provide suppression pool makeup once the HCVS is operated. According to the licensee's FIP timeline this could occur around approximately 5 hours into the ELAP event.

3.10.3 SFP Makeup

No SFP makeup is required in Phase 1. Phase 2 and Phase 3 makeup to the SFP is from the FLEX seismic deep well or circulating water discharge bay. The licensee's FIP indicates that the water from either source is available to supply makeup to the SFP within 12 hours after ELAP is initiated.

3.10.4 Containment Cooling

Other than the operation of the HCVS system and suppression pool makeup provisions described above, the licensee's strategy does not contain provisions for primary containment cooling.

3.10.5 Conclusions

Based on the FIP description, 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. If an 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 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 the fuel in the RPV, the operators can concentrate on providing makeup to the SFP. The licensee's analysis shows that, following a full core offload to the SFP, about 74 hours are available to implement makeup before boil-off results in the water level in the SFP dropping far enough to uncover fuel assemblies, and the licensee's strategy, as described in the FIP, shows that the ability to implement makeup to the SFP will occur well before that time is reached.

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. In its FIP, the licensee stated that it would follow an NEI position paper regarding shutdown/refueling modes [Reference 53] that has been endorsed by the NRC [Reference 54]. This 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 position paper, as endorsed, was subsequently incorporated into NEI 12-06, Revision 2.

Based on the licensee's implementation of the NEI position paper, as endorsed, 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 indicated that the inability to predict actual plant conditions that require the use of beyond-design-basis (BDB) equipment makes it impossible to provide specific procedural guidance. As such, the Quad Cities FSGs provide guidance that can be employed for a variety of conditions. Clear criteria for entry into FSGs will ensure 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 accomplish FLEX strategies or supplement EOPs, procedural guidance will direct the entry into and exit from the appropriate FSG procedure. The licensee also stated that FLEX strategy guidelines have been developed in accordance with BWR owners group guidelines. The FSGs provide available, pre-planned FLEX strategies for accomplishing specific tasks. The FSGs are used to supplement (not replace) the existing procedure structure that establishes command and control for the event.

3.12.2 Training

In its FIP, the licensee stated that Quad Cities' Nuclear Training Program has been revised to assure personnel proficiency in the mitigation of BDBEEs is adequate and maintained. According to the licensee, these programs and controls were developed and have been implemented in accordance with the Systematic [NRC term - Systems] Approach to Training (SAT) process. Training for both operations personnel and site emergency response leaders has been developed and implemented.

In its FIP, the licensee stated that personnel assigned to direct the execution of mitigation strategies for BDBEEs have received the necessary training to ensure familiarity with the associated tasks, considering available job aids, instructions, and mitigating strategy time constraints. Upon SAFER equipment deployment and connection in an event, turnover and familiarization training on each piece of SAFER equipment will be provided to station operators by the SAFER deployment/operating staff.

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 and will be maintained 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 42] that included the EPRI Technical Report 3002000623, "Nuclear Maintenance Applications Center: Preventive Maintenance Basis for FLEX Equipment." By letter dated October 7, 2013 [Reference 43], 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 a fleet procedure has been developed to address preventative maintenance (PM) activities using the EPRI templates or manufacturer provided information/recommendations, equipment testing, and the unavailability of equipment. The EPRI has completed and has issued "Preventive Maintenance Basis for FLEX Equipment - Project Overview Report." Preventative Maintenance Templates for the major FLEX equipment including the portable diesel pumps and generators have also been issued.

According to the licensee, the EPRI PM templates for FLEX equipment conform to the guidance of NEI 12-06, providing assurance that stored or pre-staged FLEX equipment are being properly maintained and tested. The EPRI templates are used for equipment where applicable. However, in those cases where the EPRI templates were not available, PM actions were developed based on manufacturer provided information/recommendations and an Exelon fleet procedure.

The licensee's FIP states that the unavailability of FLEX equipment and applicable connections that perform a FLEX mitigation strategy for core cooling, containment, and SFP cooling is controlled and managed per a Quad Cities procedure such that risk to mitigating strategy capability is minimized. The licensee's fifth and sixth six-month update provided a summary of the specific provisions which are described as follows:

> Exelon proposes an alternative approach to NEI 12-06, Revision 0 for protection of FLEX equipment as stated in Section 5.3.1 (seismic), Section 7.3.1 (severe storms with high winds), and Section 8.3.1 (impact of snow, ice and extreme cold). This alternative approach will be to store "N" sets of equipment in a fully robust building and the +1 set of equipment in a commercial building. For all

hazards scoped in for the site, the FLEX equipment will be stored in a configuration such that no one external event can reasonably fail the site FLEX capability (N).

To ensure that no one external event will reasonably fail the site FLEX capability (N), Exelon will ensure that N equipment is protected in the robust building. To accomplish this, Exelon will develop procedures to address the unavailability allowance as stated in NEI 12-06, Revision 0, Section 11.5.3, (see Maintenance and Testing section below for further details). This section allows for a 90-day period of unavailability. If a piece of FLEX equipment stored in the robust building were to become or found to be unavailable, Exelon will impose a shorter allowed outage time of 45 days. For portable equipment that is expected to be unavailable for more than 45 days, actions will be initiated within 24 hours of this determination to restore the site FLEX capability (N) in the robust storage location and implement-compensatory measures (e.g., move the +1 piece of equipment into the robust building) within 72 hours where the total unavailability time is not to exceed 45 days. Once the site FLEX capability (N) is restored in the robust storage location, Exelon will enter the 90-day allowed out of service time for unavailable equipment with an entry date and time based on the discovery date and time.

MAINTENANCE AND TESTING

1. The unavailability of equipment and applicable connections that directly performs a FLEX mitigation strategy for core, containment, and SFP should be managed such that risk to the mitigating strategy capability is minimized.

    a. The unavailability of plant equipment is controlled by existing plant processes such as the Technical Specifications. When plant equipment which supports FLEX strategies becomes unavailable, then the FLEX strategy affected by this unavailability does not need to be maintained during the unavailability.

    b. The required FLEX equipment may be unavailable for 90 days provided that the site FLEX capability (N) is met. If the site FLEX (N) capability is met but not protected for all of the site's applicable hazards, then the allowed unavailability is reduced to 45 days.[1]

    c. The duration of FLEX equipment unavailability, discussed above, does not constitute a loss of reasonable protection from a diverse storage location protection strategy perspective.

1. The spare FLEX equipment is not required for the FLEX capability to be met. The allowance of 90-day unavailability is based on a normal plant work cycle of 12 weeks. In cases where the remaining N equipment is not fully protected for the applicable site hazards, the unavailability allowance is reduced to 45 days to match a 6 week short cycle work period. Aligning the unavailability to the site work management program is important to keep maintenance of spare FLEX equipment from inappropriately superseding other more risk-significant work activities.

d. If FLEX equipment or connections become unavailable such that the site FLEX capability (N) is not maintained, initiate actions within 24 hours to restore the site FLEX capability (N) and implement compensatory measures (e.g., use of alternate suitable equipment or supplemental personnel) within 72 hours.

e. If FLEX equipment or connections to permanent plant equipment required for FLEX strategies are unavailable for greater than 45/90 days, restore the FLEX capability or implement compensatory measures (e.g., use of alternate suitable equipment or supplemental personnel) prior to exceeding of the 45/90 days.

For Section 5, seismic hazard, Exelon will also incorporate these actions:

1. Large portable FLEX equipment such as pumps and power supplies should be secured as appropriate to protect them during a seismic event (i.e., Safe Shutdown Earthquake (SSE) level).

2. Stored equipment and structures will be evaluated and protected from seismic interactions to ensure that unsecured and/or non-seismic components do not damage the equipment.

For Section 7, severe storms with high winds, Exelon will also incorporate this action:

- For a 2-unit site, 3 sets (N+1) of on-site FLEX equipment are required. The plant screens in per Sections 5 through 9 for seismic, flooding, wind (both tornado and hurricane), snow, ice and extreme cold, and high temperatures.

    - To meet Section 7.3.1.1.a, either of the following are acceptable:
    - All three sets (N+1) in a structure(s) that meets the plant's design basis for high wind hazards, or
    - Two sets (N) in a structure(s) that meets the plant's design basis for high wind hazards and one set (+1) stored in a location not protected for a high wind hazard.

For Section 8, impact of snow, ice and extreme cold, Exelon will also incorporate this action:

- Storage of FLEX equipment should account for the fact that the equipment will need to function in a timely manner. The equipment should be maintained at a temperature within a range to ensure its likely function when called upon. For example, by storage in a heated enclosure or by direct heating (e.g., jacket water, battery, engine block heater, etc.).

Exelon will meet all of the requirements in NEI 12-06, Revision 0 for Section 6.2.3.1 for external flood hazard and Section 9.3.1 for impact of high temperatures.

The licensee's seventh six-month update, as well as the FIP, state that NEI 12-06, Revision 2, incorporated this change in compliance method, and therefore this alternative is no longer necessary.

The NRC reviewed these unavailability provisions and concludes that they are consistent with NEI 12-06, Revision 2, and are therefore acceptable. The staff also notes that the licensee's FIP Section 13.3, contains a shortened version of the unavailability criteria that appear to be based on the provisions of NEI 12-06, Revision 0, even though the licensee's FIP is based on NEI 12-06, Revision 2. Since NEI 12-06, Revision 0, was also endorsed by the staff, meeting the provisions of NEI 12-06, Revision 0 would also be acceptable.

Further, the NRC staff concludes 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 2

3.14.1 Seismic Water Source Alternative Approach

The licensee's FIP identifies one alternative to NEI 12-06, Revision 2, relating to the seismic water source. According to the licensee's FIP, for periods of unavailability of the seismic well, an alternative approach is desired.

The backup source of water in Phases 2 and 3 for the seismic well is the circulating water discharge bay. The circulating water discharge bay has not been specifically evaluated for seismic capability and therefore does not meet the definition of robust as stipulated in NEI 12-06, Revision 2. However, the licensee asserts that the circulating water bay will remain available after a seismic event due to the size of the two diffuser pipes which connect the bay to the Mississippi River. In addition, time is available to deploy an NSRC-supplied submersible pump in the event of a low river level condition caused by a postulated downstream dam failure. The licensee's proposed alternative is based on the protection provisions relating to unavailability specified in NEI 12-06, Revision 2, and are described in the FIP as follows:

1. The unavailability of the seismic deep well equipment and applicable connections that directly performs a FLEX mitigation strategy for core, containment, and SFP should be managed such that risk to mitigating strategy capability is minimized.

    a. The unavailability of installed plant equipment is controlled by existing plant processes such as the Technical Specifications. When installed plant equipment which supports FLEX strategies becomes unavailable, then the FLEX strategy affected by this unavailability does not need to be maintained during the unavailability.
    b. The required seismic deep well equipment may be unavailable for 90 days provided that the site seismic water supply capability is met. If the site seismic water supply capability is met but not fully protected for the site's applicable hazards, then the allowed unavailability is reduced to 45 days.
    c. If seismic deep well equipment or connections becomes unavailable such that the site seismic water supply capability is not maintained, initiate actions within

24 hours to restore the site seismic water supply capability and implement compensatory measures (ensure equipment for use of the discharge bay water supply is ready for deployment) within 72 hours, and then initiate a concurrent 45 day period to repair the seismic well to full availability.

d. If seismic deep well permanently installed equipment required for FLEX strategies are expected to be unavailable for greater than 45 days, initiate actions to restore the seismic deep well capability and implement compensatory measures (e.g., use of alternate suitable equipment) prior to exceeding the 45 days.

The licensee's FIP also describes the actions that will be taken during maintenance or testing should the deep well become unavailable. These actions include restoring the well pump to operation within 45 days.

The NRC staff reviewed the proposed alternative and finds that the licensee's proposal is substantially similar to the provisions of NEI 12-06, Revision 2. The staff concludes that the licensee's plan for responding to a seismic event with the seismic well pump out of service should still accomplish the necessary water supply function with the diesel-driven FLEX pump when the provision for obtaining a submersible pump from the NSRC is included, while also considering the 45-day action time for well pump restoration.

In conclusion, the NRC staff finds that although the guidance of NEI 12-06 has not been met, if this alternative is 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 28, 2013 [Reference 29], the licensee submitted its OIP for Quad Cities in response to Order EA-12-051. By letter dated June 7, 2013 [Reference 30], supplemented by e-mail dated June 25, 2013 [Reference 31], the NRC staff sent a request for additional information (RAI) to the licensee. The licensee provided a response to the RAI by letter dated July 3, 2013 [Reference 32]. By letter dated October 9, 2013 [Reference 33], the NRC staff issued an ISE and RAI to the licensee. By letter dated November 26, 2013 [Reference 34], the NRC sent an additional RAI to the licensee.

By letters dated August 28, 2013 [Reference 35], February 28, 2014 [Reference 36], August 28, 2014 [Reference 37], and February 27, 2015 [Reference 38], the licensee submitted status reports for the OIP and the RAI in the ISE. The OIP describes the strategies and guidance to be implemented by the licensee for the installation of reliable SFP level instrumentation which will function following a BDBEE, including modifications necessary to support this implementation, pursuant to Order EA-12-051. By letter dated May 7, 2015

[Reference 39], the licensee reported that full compliance with the requirements of Order EA-12-051 was achieved at both units.

The licensee has installed a SFP level instrumentation system designed by Westinghouse. The NRC staff reviewed the vendor's SFP level instrumentation system design specifications, calculations and analyses, test plans, and test reports during a vendor audit. The staff issued an audit report regarding the Westinghouse system on August 18, 2014 [Reference 40]. The staff also performed an onsite audit to review the implementation of SFP level instrumentation related to Order EA-12-051 at Quad Cities. The scope of the audit included verification of: (a) whether the site's seismic and environmental conditions are enveloped by the equipment qualifications; (b) whether the equipment installation met the requirements and vendor's recommendations; and (c) whether program features met the order requirements. By letter dated June 25, 2015 [Reference 24], the NRC issued an audit report on the licensee's progress.

According to the licensee's OIP, the two Quad Cities units share a common Reactor Building refueling floor that contains two SFPs, one for each unit. The two pools are normally hydraulically connected such that the level in both SFPs is the same. Thus, the licensee's two installed SFP indication channels (one in each pool) will monitor the level in both pools as long as the hydraulic connection is maintained.

4.1 Levels of Required Monitoring

The NRC staff, in the Quad Cities ISE prepared for Order EA-12-051, reviewed the proposed levels for Quad Cities based on information in the licensee's SFP level instrumentation OIP and RAI response letter dated July 3, 2013. The staff found that Level 1 at 689'-3" is adequate for proper SFP cooling system operation and provides adequate net positive suction head for SFP cooling pump operation. Regarding Level 2, the staff found that the licensee's designated level of 676'-2" corresponds to an elevation that is at least 10 feet above the spent fuel seated in the fuel rack and thus provides adequate shielding for a person standing on the SFP operating deck. The staff found that Level 3 at 666'-2" encompasses the highest point of any fuel rack seated in the SFP.

In its second six-month update, the licensee revised Level 3 to a slightly higher elevation of 666'-8 1/2" to make it consistent with the bottom of the gate opening between the two pools such that either instrument can provide full and continuous indication down to Level 3. Since this elevation is conservatively higher that the originally designated Level 3, the staff concludes that it continues to meet the provisions of NEI 12-02, where actions to implement makeup water addition should no longer be deferred.

Based on the ISE evaluation, along with the clarification for Level 3 described 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 requires that the SFP level instrumentation shall include specific design features, including specifications on the instruments, arrangement, mounting, qualification, independence, power supplies, accuracy, testing, and display. Below is the staff's assessment of the design features of the SFP level instrumentation.

4.2.1 Design Features: Instruments

In its first and third six-month updates, the licensee stated it would use the Westinghouse SFP level instrumentation system for both channels, with the primary fixed instrument installed in the Unit 1 SFP and the secondary fixed instrument installed in the Unit 2 SFP. The NRC staff's review of the Westinghouse design is documented in the vendor audit report [Reference 40]. The licensee provided a sketch of the Quad Cities instrument configuration in its third six-month update. This sketch shows that the primary probe is mounted in the northeast corner of the Unit 1 SFP and the secondary probe is mounted in the southeast corner of the Unit 2 SFP. With the interconnected pool arrangement and the licensee's designation of Level 3 corresponding to the bottom of the gate opening between the pools, the staff concludes that either instrument can provide full and continuous indication for both SFPs from Level 1 down to Level 3.

Based on the licensee's description and the Westinghouse audit results, the NRC staff finds that the licensee's design, with respect to the number of channels and measurement range for its SFP, 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 Design Features: Arrangement

The primary and secondary probe locations are described above. In the third six-month update, the licensee provided a sketch showing the sensor layout, as well as the general routing of the signal cables in the SFP area. The licensee's sketch shows the signal cables proceeding west, through conduits embedded in the concrete of the refueling floor. The NRC staff confirmed, during the on-site audit, that the distance between the primary and secondary instruments is in accordance with the provisions of NEI 12-02, Section 3.2. Based on the licensee's sketch, confirmed by the audit walk down, the NRC staff concludes that there is sufficient channel separation within the SFP area between the channels to provide reasonable protection against loss of indication of SFP level due to 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 SFP level instrumentation 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

Order EA-12-051 and NEI 12-02 specify that installed instrument channel equipment within the SFP shall retain its design configuration during and following the maximum seismic ground motion considered in the design of the SFP structure. In its third six-month update, the licensee provided a sketch of the mounting bracket used to support the probe and signal cable at the pool edge. The bracket is a cantilever design that is welded to a stainless steel plate embedded in the refueling floor and extends over the poolside curb. During the onsite audit, the NRC staff reviewed portions of the licensee's engineering design package specifying the mounting arrangements for the SFP level instrumentation and found the methodology and analyses to be consistent with the guidance contained in NEI 12-02, including the anticipated seismic loading and hydrodynamic loading caused by pool sloshing.

During the on-site audit, the NRC staff also questioned the mounting location of the electronics in the Turbine Building because the building is not considered to be a Safety Class I structure, as described in the Quad Cities UFSAR. The staff also noted that the licensee's UFSAR, Section 3.2, describes the Reactor Building as Safety Class I and describes several cases where Class I items are located in non-Class I buildings, including the Turbine Building. The NRC staff reviewed portions of the licensee's engineering design package specifying the mounting arrangements for the SFP level instrumentation electronics and displays and concluded that they are installed in accordance with site Seismic Category I standards. The NRC staff also observed that the Reactor Building wall provides some protection to the instruments as well. During the on-site walkdown, the staff further noted that there are multiple operator pathways to the display locations from the MCR and judged that the operators should have access to SFP level indication following a seismic event.

Based on the evaluation above, the NRC staff finds that the licensee's proposed mounting 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.

4.2.4 Design Features: Qualification

4.2.4.1 Augmented Quality Process

Appendix A-1 of the guidance in NEI 12-02 describes a quality assurance process for non-safety systems and equipment that are not already covered by existing quality assurance requirements. In 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 reliability of the instrumentation would be assured through compliance with the guidance (NEI 12-02, as endorsed). Further, the licensee also stated that reliability would be established using an augmented quality assurance process.

Based on the licensee's OIP description, 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 Instrument Channel 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 component use 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.

The NRC staff reviewed the vendor (Westinghouse) qualification testing and results during the vendor audit which is documented in letter dated August 18, 2014. The Quad Cities SFP level instrumentation configuration has only passive components in the SFP area. These components contain no electronic devices and are qualified for the anticipated environment of 212°F with 100 percent humidity.

In its third six-month update, the licensee stated that the radiation total integrated dose (TID) in the Quad Cities SFP area is 4E07 Rads with the SFP water level at Level 3. Westinghouse qualified the components in the SFP area to 1E07 Rads. The licensee stated that at Level 2 the TID reduces to 2E07 Rads and at Level 1 the TID reduces to 8E06 Rads. The licensee's third six-month update also stated that the only components potentially exposed to these levels of radiation are the probe and anchor, which are made of stainless steel and are resistant to radiation effects. The staff notes that according to the FIP submitted for Order EA-12-049, the licensee anticipates that SFP level makeup will begin at approximately 12 hours into the event, well in advance of the earliest projected time to reach Level 3 (approximately 74 hours, with a full core offload). By maintaining SFP level well above Level 3, the staff concludes that the radiation qualification of the SFP level instrumentation components in the SFP area should not be challenged.

Outside the SFP area, the electronics and displays for each unit are seismically mounted in the Turbine Building, on the Reactor Building wall, outside the MCR. This location was chosen due to its milder environment and proximity to the MCR. In its third six-month update, the licensee stated the environmental conditions in the Turbine Building near the electronics/displays are projected to be a maximum temperature of 120°F, while Westinghouse qualified the equipment to operate up to 140°F. The radiation environment from SFP source term is projected to be extremely low in the Turbine Building, well below the Westinghouse qualification level of the electronics components (TID of 1E03 Rads), even if SFP water level reaches Level 3.

Based on the licensee's six-month update information, supplemented by the Westinghouse audit results, the NRC staff finds that 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 <u>Design Features: Independence</u>

As described in Section 4.2.1 of this safety evaluation the two probes, as mounted, have approximately 33 feet of separation. The signal wires are then routed in conduits embedded in the refueling floor. Outside the refueling area, the separation of Unit 1 and Unit 2 SFP level instrumentation wiring increases as the wiring is routed to the transmitter and display locations in the Turbine Building. The display locations are also separated by approximately 50 feet, with the displays located in each unit's respective Turbine Building.

Electrical separation is maintained by providing power from separate Unit 1 and Unit 2 instrument busses. In its third six-month update, the licensee stated that Unit 1 and Unit 2 SFP level instruments are powered from motor control centers (MCCs) 18-2 and 28-2, respectively. During the on-site audit, the NRC staff reviewed drawings 4E-1321, "Key Diagram 120-240V AC Instrument Bus PNL 901-50," and 4E-2321, "Key Diagram PNL 902-50 120-240V AC Instrument Bus," to confirm electrical separation is maintained down to the panel level.

Based on the licensee's description, confirmed by the audit review, the NRC 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

As described in the previous section of this safety evaluation, the Unit 1 and Unit 2 SFP level instruments are powered from Unit 1 and Unit 2 instrument busses which are fed from EDG-backed MCCs 18-2/28-2. In its third six-month update, the licensee further clarified that the SFP level instruments have batteries that will automatically maintain continuous channel operation for 72 hours, upon loss of the normal power supply. MCCs 18-2/28-2 are restored in the licensee's BDBEE mitigating strategy by the FLEX DGs to restore power before the batteries are depleted. The licensee also stated that the SFP level instruments also have a receptacle and selector switch that can be used to power the SFP level instruments from an alternate external generator, if needed.

Based on the licensee's description, 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

The NRC staff reviewed the accuracy of the Westinghouse SFP level instrumentation system during the vendor audit and found that it met the guidance. Details are available in the vendor audit report dated August 18, 2014. The licensee's third six-month updates states that individual channel accuracy is expected to be ± 3 inches during both normal and BDB conditions. The staff observes that this accuracy meets the NEI 12-02 accuracy provision of ±12 inches.

Based on the vendor audit results and the licensee's third six-month update, the NRC 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

The NRC staff's review of the testing of the Westinghouse SFP level instrumentation is documented the vendor audit report [Reference 40]. The Westinghouse design uses a "two point" test where a technician raises the flexible probe cable a measured distance out of the water and confirms the corresponding change on the display. The design also offers a calibration test that removes the probe from the launch plate above the pool and installs it in a test fixture that includes a movable level simulator. Calibration can be verified over the entire length of the probe. In its third six-month update, the licensee described how it will incorporate

Westinghouse established procedures for testing the SFP level instrumentation into Quad Cities Station preventive maintenance tasks.

Based on the vendor audit results and the licensee's third six-month update, the NRC staff finds that the licensee's proposed SFP instrumentation design allows for testing 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

In its third six-month update, the licensee stated that the displays are located on the main turbine floor, mounted on the Reactor Building wall, outside the MCR. The licensee also stated, in part, the area is expected to remain habitable, citing maximum conditions of 120°F, 90 percent humidity and a dose rate of 1.8E-08 Rem/hour. The dose rate was based on SFP source term with water at Level 3 (top of the fuel rack).

As previously noted, the NRC staff observes that the Turbine Building itself is not a Seismic Category I structure. However, as described in Section 4.2.3 of this safety evaluation, the staff concludes that the displays should survive a BDB seismic event. Further, separation of the Unit 1 and Unit 2 displays and diverse travel paths provide further assurance the displays will be accessible following a seismic event. The NRC staff observed the display location's proximity to the MCR during the on-site audit and also observed the separation of the displays.

Based on the licensee's description, confirmed by the onsite audit walk down, the NRC staff finds that the licensee's proposed location and design of the SFP instrumentation 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

Order EA-12-051 specified that the spent fuel pool instrumentation shall be maintained available and reliable through appropriate development and implementation programmatic controls, including training, procedures, and testing and calibration. Below is the NRC staff's assessment of the programmatic controls for the spent fuel pool instrumentation.

4.3.1 Programmatic Controls: Training

In its OIP, the licensee stated that personnel performing functions associated with these SFP level instrumentation channels will be trained to perform the job specific functions (maintenance, calibration, surveillance, etc.). The licensee also stated that training will be consistent with equipment vendor guidelines, instructions and recommendations and the SAT will be used to identify the population to be trained and to determine the initial and continuing elements of the required training. In it full compliance letter, the licensee stated that training for Quad Cities Nuclear Power Station, Units 1 and 2, has been completed.

Based on the licensee's description, the NRC staff finds that the plan to train personnel in the operation, maintenance, calibration, and surveillance of the SFP level instrumentation at Quad Cities, 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

In its OIP, the licensee stated that site procedures will be developed using guidelines and vendor instructions to address the maintenance, operation and abnormal response issues associated with the primary and backup channels of SFP instrumentation. In its third six-month update letter dated August 28, 2014, the licensee stated these procedures will be developed in accordance with Exelon's procedural control process. Technical objectives to be achieved in each of the respective procedures are described below:

- System Inspection: To verify that system components are in place, complete, and in the correct configuration, and that the sensor probe is clean.
- Calibration and Test: To verify that the system is within the specified accuracy, is functioning as designed, and is appropriately indicating SFP water level.
- Maintenance: To establish and define scheduled and preventive maintenance requirements and activities necessary to minimize the possibility of system interruption.
- Operation: To provide sufficient instructions for operation and use of the system by plant operations staff. To specify troubleshooting/diagnostics information to help identify component repair and replacement activities in the event of system malfunction, as appropriate.
- Responses: To define the actions to be taken upon observation of system level indications, including actions to be taken at the levels defined in NEI 12-02.

In its full compliance letter, the licensee stated that operating and maintenance procedures have been developed and integrated with existing procedures.

Guidance document NEI 12-02 states that procedures will be developed using guidelines and vendor instructions to address the maintenance, operation, and abnormal response issues associated with the instrumentation. It also states that licensees will have a strategy to ensure SFP water level addition is initiated at an appropriate time based on the mitigating strategies developed in response to Order EA-12-049.

Based on the licensee's description, the staff finds that the licensee's procedure development appears to be consistent with NEI 12-02, as endorsed by JLD-ISG-2012-03. Thus, if implemented as described, the licensee's procedure development should adequately address the requirements of Order EA-12-051.

4.3.3 Programmatic Controls: Testing and Calibration

In its third six-month update, the licensee stated that functional checks and operator performance checks will be contained in plant operating procedures and performed periodically based on the vendor's recommendation. The licensee also stated manual calibration and operator performance checks are planned to be performed periodically with additional maintenance being performed, as needed, when flagged by the automated diagnostic testing features. In addition, the licensee stated that it will stock spare parts to diminish the likelihood of one or both channels being out of service for an extended period of time. In its full compliance letter, the licensee stated that maintenance procedures have been developed and integrated with existing procedures and that site processes have been established to ensure the instruments are maintained at their design accuracy.

In its third six-month update letter dated August 28, 2014, the licensee provided the planned compensatory actions for extended out-of-service events which are summarized as follows:

Number of Channel(s) Out-of-Service	Required Restoration Action	Compensatory Action if Required Restoration Action Not Completed Within Specified Time
1	Restore Channel to functional status within 90 days (or if channel restoration not expected within 90 days, then proceed to Compensatory Action)	Immediately initiate action in accordance with note below
2	Initiate action within 24 hours to restore one channel to functional status and restore one channel to functional status within 72 hours	Immediately initiate action in accordance with note below

Note: Present a report to the onsite Plant Operations Review Committee within the following 14 days. The report shall outline the planned alternate method of monitoring, the cause of the non-functionality, and the plans and schedule for restoring the instrumentation channel(s) to functional status.

Guidance document NEI 12-02 states that the testing and calibration of the instrumentation shall be consistent with the vendor recommendations or other documented basis. Based on the licensee's submittals, the NRC staff concludes that the licensee's testing and calibration plan appears to be consistent with the vendor recommendations. Further, the staff concludes that the licensee's maintenance program also 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 plan 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 OIP dated February 28, 2013 [Reference 29], the licensee stated that they would meet 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 has conformed to the guidance in NEI 12-02, as endorsed by JLD-ISG-2012-03. In addition, the NRC staff concludes that if the SFP level instrumentation is installed at Quad Cities 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 January 2015 [Reference 24]. The licensee reached its final compliance date on June 15, 2018, for Order EA-12-049, and March 22, 2015 for Order EA-12-051, and has declared that both reactors are in compliance with the orders. The purpose of this safety evaluation 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.

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SUBJECT: QUAD CITIES NUCLEAR POWER STATION, UNITS 1 AND 2 – 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. MF1048, MF1049, MF1052, AND MF1053; EPID NOS. L-2013-JLD-0019 AND L-2013-JLD-0020) DATED December 13, 2018

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