UNITED STATES
NUCLEAR REGULATORY COMMISSION
REGION IV
1600 E LAMAR BLVD
ARLINGTON, TX 76011-4511

January 22, 2015

EA-14-088

Jeremy Browning, Site Vice President
Entergy Operations, Inc.
Arkansas Nuclear One
1448 SR 333
Russellville, AR 72802-0967

SUBJECT: ARKANSAS NUCLEAR ONE, UNITS 1 AND 2 - FINAL SIGNIFICANCE DETERMINATION OF YELLOW FINDING AND NOTICE OF VIOLATION; NRC INSPECTION REPORT 05000313/2014010 AND 05000368/2014010

Dear Mr. Browning:

This letter provides you the final significance determination of the preliminary Yellow finding identified in NRC Inspection Report 05000313/2014009; 05000368/2014009 (ML14253A122), dated September 9, 2014. A detailed description of the finding is contained in Section 1R01 of that report. The finding was associated with the failure to design, construct, and maintain the Unit 1 and Unit 2 auxiliary building and emergency diesel fuel storage building flood barriers so that they could protect safety-related equipment from flooding.

At your request, a Regulatory Conference was held on October 28, 2014, to further discuss your views on these findings. A copy of your presentation provided at this meeting is attached to the summary of the Regulatory Conference (ML14329B209), dated November 25, 2014. In your presentation on the risk significance of the finding, you discussed methodologies used by Entergy to develop a probable maximum precipitation and probable maximum flood for the Arkansas Nuclear One site, including development of an annual exceedance probability for the probable maximum flood. You also described mitigation strategies/recovery actions that could have been implemented prior to and in the event of flooding at the site to limit the consequences of the flooding performance deficiencies. Specifically, you presented mitigating strategies to protect site structures and equipment from flood waters, such as installation of an aqua-berm and sandbagging. You also discussed two methods for maintaining reactor core heat removal by providing feedwater to the steam generators from either the service water system or from a portable diesel-driven pump.

Based on your staff's evaluation of the probability of success of implementing those mitigating strategies/recovery actions, as well as your staff's estimated initiating event frequencies for external flooding events that would result in flood water elevations above a site grade level of 354 feet Mean Sea Level (MSL) and 356 feet MSL, your staff concluded that the change in core damage frequency from external flooding would be 7.99×10^{-7}/yr for Unit 1 and Unit 2. Your staff also determined that there would be additional risk for Unit 2 from an internal flooding event, and minimal additional risk for Unit 1 from internal flooding. With the implementation of similar mitigating strategies/recovery actions, your staff determined that the change in core damage frequency from external and internal flooding events would be 1.36×10^{-6}/yr for Unit 2. As a result, you concluded that the inspection finding should be characterized as Green, or very low safety significance, for Unit 1, and White, or low-to-moderate safety significance, for Unit 2.

After thoroughly considering the information developed during our inspections and the information you provided at the Regulatory Conference, we have concluded that the significance of this finding is most appropriately determined using Inspection Manual Chapter 0609, Appendix M, "Significance Determination Process Using Qualitative Criteria." We concluded that the safety significance for the finding involving flooding deficiencies for Unit 1 and Unit 2 is Yellow, a finding having substantial safety significance. This determination was based on qualitative factors due to the high degree of uncertainty that is associated with the estimation of the frequency of an external flooding event. In addition, following the Regulatory Conference, NRC inspectors identified that the mitigation strategies/recovery actions were more complicated or would not work as you presented. We have concluded that some recovery credit is warranted; however, the amount of recovery credit is less than you proposed during the Regulatory Conference. Details regarding our evaluation of the risk significance of the finding are provided in Enclosure 2 of this letter.

You have 30 calendar days from the date of this letter to appeal the staff's determination of significance for the identified Yellow findings. Such appeals will be considered to have merit only if they meet the criteria provided in Inspection Manual Chapter 0609, "Significance Determination Process," Attachment 2. An appeal must be sent in writing to the Regional Administrator, Region IV, 1600 E. Lamar Blvd., Arlington, TX 76011-4511.

The NRC has also determined that the failure to design, construct, and maintain the Unit 1 and Unit 2 auxiliary building and emergency diesel fuel storage building flood barriers so that they would protect safety-related equipment from flooding, is a violation of Title 10 of the Code of Federal Regulations (CFR) Part 50, Appendix B, Criterion III, "Design Control," and Criterion V, "Instructions, Procedures, and Drawings," as cited in the attached Notice of Violation (Notice). The circumstances surrounding the violations were described in detail in NRC Inspection Report 05000313/2014009; 05000368/2014009. In accordance with the NRC's Enforcement Policy, NRC issuance of this Notice is considered escalated enforcement action because it is associated with a Yellow finding.

You are required to respond to this letter and should follow the instructions specified in the enclosed Notice when preparing your response. If you have additional information that you believe the NRC should consider, you may provide it in your response to the Notice. The NRC's review of your response to the Notice will also determine whether further enforcement action is necessary to ensure compliance with regulatory requirements.

Because plant performance at the Arkansas Nuclear One facility has been determined to be beyond the "Licensee Response Column" of the NRC's Reactor Oversight Process Action Matrix, as a result of Yellow significance findings for Units 1 and 2, the NRC will use the Action Matrix to determine the most appropriate NRC response to the findings' significance. We will notify you, by separate correspondence, of that determination.

In accordance with 10 CFR 2.390 of the NRC's "Rules of Practice and Procedure," a copy of this letter, its enclosures, and your response will be made available electronically for public inspection in the NRC's Public Document Room or from the NRC's Agencywide Documents Access and Management System (ADAMS), accessible from the NRC website at http://www.nrc.gov/reading-rm/adams.html. To the extent possible, your response should not include any personal privacy, proprietary, or safeguards information so that it can be made available to the Public without redaction.

Sincerely,

/RA/

Marc L. Dapas
Regional Administrator

Dockets: 50-313; 50-368
Licenses: DPR-51; NPF-6

Enclosures:
1. Notice of Violation
2. Final Significance Determination

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See next page

ADAMS ACCESSION NUMBER: ML15023A076

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Letter to Jeremy Browning from Marc L. Dapas dated January 22, 2015

SUBJECT: ARKANSAS NUCLEAR ONE, UNITS 1 AND 2 - FINAL SIGNIFICANCE DETERMINATION OF YELLOW FINDING AND NOTICE OF VIOLATION; NRC INSPECTION REPORT 05000313/2014010 AND 05000368/2014010

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Electronic Distribution via Listserv for Arkansas Nuclear One, Units 1 and 2

NOTICE OF VIOLATION

Entergy Operations, Inc.
Arkansas Nuclear One, Units 1 and 2

Dockets: 50-313, 50-368
Licenses: DRP-51, NPF-6
EA-14-088

During an NRC inspection conducted between February 10, 2014, and August 1, 2014, two violations of NRC requirements were identified. In accordance with the NRC Enforcement Policy, the violations are listed below:

A. 10 CFR Part 50, Appendix B, Criterion III, "Design Control," states, in part, that measures shall be established to assure that applicable regulatory requirements and the design basis, as defined in § 50.2 and as specified in the license application, for those structures, systems, and components to which this appendix applies, are correctly translated into specifications, drawings, procedures, and instructions. Design changes shall be subject to design control measures commensurate with those applied to the original design.

Unit 1, Safety Analysis Report (SAR), Amendment 26, Section 5.1.6, "Flooding," defined the design basis and stated, in part, that seismic class 1 structures are designed for the maximum probable flood level at elevation 361 feet above Mean Sea Level (MSL). The Unit 1 SAR further stated that all seismic class 1 systems and equipment are either located on floors above elevation 361 feet or protected. Sections 5.3.2 and 5.3.5.2 of the SAR indicated that the auxiliary building and emergency diesel fuel storage vault, both quality-related, are seismic class 1 structures.

Unit 2, Safety Analysis Report, Amendment 25, Section 3.4.4, "Flood Protection," defined the design basis and stated, in part, that seismic category 1 structures were designed for the probable maximum flood. The Unit 2 SAR further stated that all category 1 systems and equipment are either located on floors above elevation 369 feet, or protected. Table 3.2-2, "Seismic Categories of Systems, Components, and Structures," of the Unit 2 SAR indicated that the auxiliary building and emergency diesel fuel storage vault, both quality-related, are seismic class 1 structures.

Unit 1, Safety Analysis Report, Amendment 26, Section 5.3.2, "Auxiliary Building," stated, in part, that the floor area at elevation 317 feet containing engineered safeguards equipment, was partitioned into separate rooms to provide protection in the event of flooding due to a pipe rupture.

Contrary to the above, as of March 31, 2013, the licensee failed to assure that applicable regulatory requirements and the design basis were correctly translated into specifications, drawings, procedures, and instructions and that design changes were subject to design control measures commensurate with those applied to the original design. Specifically, the licensee failed to assure that safety-related equipment below the design flood level was protected in the following examples:

a. The licensee failed to include a procedural step to install a blind flange in a ventilation duct that penetrated the Unit 1 auxiliary building below the design flood level.

b. The licensee failed to design the floor drain system with isolation capability so that the drain piping from the turbine building and radwaste storage building, which are non-flood protected structures, would not allow water to drain into the Unit 1 auxiliary building in the event of a flood.

c. The licensee failed to design the Unit 1 Hatch 522 and Unit 2 Door 253, which allow access to the area between the auxiliary buildings and containment buildings, to prevent water intrusion during a design basis flood event.

d. The licensee failed to seal open penetrations into the Unit 1 auxiliary building below the design flood level that were created when the licensee abandoned portions of the waste solidification system.

e. The licensee failed to assure that the Unit 1 decay heat vault drain valves were specified as safety-related, as required to maintain the vaults watertight.

B. 10 CFR Part 50, Appendix B, Criterion V, "Instructions, Procedures, and Drawings," states, in part, that activities affecting quality shall be prescribed by documented instructions, procedures, or drawings of a type appropriate to the circumstances and shall be accomplished in accordance with these instructions, procedures, or drawings.

Unit 1 Quality Drawing A-304, Sheet 1, "Wall and Floor Penetrations Key Plan," Revision 1, and Unit 2, Quality Drawings A-2002, "Architectural Schematic, Fire and Flood Protection Plans and Sections," Revision 10, prescribed walls, ceilings, and floors as flood barriers that required seals.

Unit 1, Quality Drawing A-337, "Wall and Floor Penetrations Enclosure Details," Revision 9, and Unit 2 Quality Drawing Series E-2073, "Electrical Penetration Sealing Details," Revision 3, prescribed conduit seal installation details that would act as a barrier to flood water. Unit 2 Quality Drawing Series A-2600, "Fire Barrier Penetration Seal Details," Revision 5, prescribed pipe penetration seal details that would act as a barrier to flood water.

Contrary to the above, as of March 31, 2013, the licensee did not accomplish activities affecting quality in accordance with documented instructions, procedures, or drawings. Specifically, the licensee failed to assure that safety-related equipment below the design flood level was protected in the following examples:

a. The licensee failed to install seals in conduits that penetrated flood barriers for the Unit 1 and Unit 2 auxiliary and emergency diesel fuel storage buildings.

b. The licensee failed to install seals in piping that penetrated flood barriers for the Unit 2 auxiliary building extension.

c. For the Unit 1 and Unit 2 auxiliary building hatches and building expansion joints between the building and containment, the licensee failed to provide appropriate seal inspection criteria, establish a replacement frequency for the seals, and develop post-maintenance test procedures to verify the effectiveness of the seals after they were reinstalled.

These violations are associated with a Yellow Significance Determination Process finding for Units 1 and 2.

Pursuant to the provisions of 10 CFR 2.201, Entergy Operations, Inc., is hereby required to submit a written statement or explanation to the U.S. Nuclear Regulatory Commission, ATTN: Document Control Desk, Washington, DC 20555-0001 with a copy to the Regional Administrator, Region IV, and a copy to the NRC Resident Inspector at Arkansas Nuclear One, within 30 days of the date of the letter transmitting this Notice of Violation (Notice). This reply should be clearly marked as a "Reply to a Notice of Violation; EA-14-088" and should include for each violation: (1) the reason for the violation, or, if contested, the basis for disputing the violation or severity level; (2) the corrective steps that have been taken and the results achieved; (3) the corrective steps that will be taken; and (4) the date when full compliance will be restored.

Your response may reference or include previous docketed correspondence, if the correspondence adequately addresses the required response. If an adequate reply is not received within the time specified in this Notice, an order or a Demand for Information may be issued as to why the license should not be modified, suspended, or revoked, or why such other action as may be proper should not be taken. Where good cause is shown, consideration will be given to extending the response time.

If you contest this enforcement action, you should also provide a copy of your response, with the basis for your denial, to the Director, Office of Enforcement, United States Nuclear Regulatory Commission, Washington, DC 20555-0001.

Because your response will be made available electronically for public inspection in the NRC Public Document Room or from the NRC's document system (ADAMS), accessible from the NRC Web site at http://www.nrc.gov/reading-rm/adams.html, to the extent possible, it should not include any personal privacy, proprietary, or safeguards information so that it can be made available to the public without redaction. If personal privacy or proprietary information is necessary to provide an acceptable response, then please provide a bracketed copy of your response that identifies the information that should be protected and a redacted copy of your response that deletes such information.

If you request withholding of such material, you <u>must</u> specifically identify the portions of your response that you seek to have withheld and provide in detail the bases for your claim of withholding (e.g., explain why the disclosure of information will create an unwarranted invasion of personal privacy or provide the information required by 10 CFR 2.390(b) to support a request for withholding confidential commercial or financial information). If safeguards information is necessary to provide an acceptable response, please provide the level of protection described in 10 CFR 73.21.

Dated this 22nd day of January 2015

ARKANSAS NUCLEAR ONE
Final Significance Determination
Unit 1 and Unit 2 Flooding Deficiencies

As described in NRC inspection report 05000313/2014009; 05000368/2014009 (ADAMS ML14253A122), the NRC used Inspection Manual Chapter (IMC) 0609, Appendix M, "Significance Determination Process Using Qualitative Criteria", Table 4.1, "Qualitative Decision-Making Attributes for NRC Management Review", to determine the preliminary risk significance for the finding associated with the flooding deficiencies at ANO, Units 1 and 2. The NRC concluded that the preliminary risk significance for the subject flooding deficiencies should be characterized as Yellow, meaning a finding of substantial risk. During the Regulatory Conference held on October 28, 2014, the licensee provided additional information concerning the frequency of significant flooding at ANO, and mitigating startegies/recovery actions that could be taken prior to, and during, a site flooding event. The licensee concluded, based on its extensive analysis, that the risk significance for Unit 1 should be characterized as Green (very low safety significance), and for Unit 2, it should be characterized as White (low to moderate safety significance).

The NRC thoroughly reviewed the information provided by the licensee during the Regulatory Conference and completed additional inspections to validate proposed mitigation strategies/recovery actions. The NRC concluded that a final significance determination of substantial risk (Yellow) for the flooding deficiencies on Unit 1 and Unit 2 is appropriate. The following sections of this enclosure discuss the NRC's evaluation of the information presented by the licensee and provide the basis for the NRC's final risk determination.

A. ANALYSIS OF LICENSEE INFORMATION USING IM 0609, APPENDIX M CRITERIA

1. Bounding Risk Evaluation

   The current licensing bases for ANO is a Probable Maximum Flood (PMF) event coincident with a failure of the upstream Ozark Dam, requiring protection of the Seismic Category I structures from a flood elevation of 361 feet above Mean Sea Level (MSL), which is 7 feet above the site grade level of 354 feet MSL. Note that all elevations in this enclosure are referenced to MSL. As part of its analysis in developing a response to the NRC's 10 CFR 50.54(f) letter pertaining to the Fukushima Lessons-Learned Near-Term Task Force (NTTF) Recommendation 2.1 for flooding reevaluation, the licensee derived preliminary results for site flood elevations for a PMF based on current approaches and state-of-the-art methodologies. During the Regulatory Conference, the licensee provided a number of different estimates to establish the likelihood of severe flooding at ANO. It is the NRC's understanding that these preliminary results and supporting calculations will be submitted to the NRC for full review as part of the licensee's flooding reevaluation in connection with the 10 CFR 50.54(f) letter response. Consideration of the information presented by the licensee relative to the NRC's final significance determination should not be interpreted as acceptance or rejection of the flooding reevaluation associated with the licensee's 10 CFR 50.54(f) response. But rather, this information has been evaluated in the context of making a risk-informed enforcement decision on flood protection related performance deficiencies at ANO. Subsequent evaluation of this information under the NRC's formal review process for the licensee submitted flooding reevaluation may or may not result in changes to the ANO flood elevation estimates.

The licensee presented information to highlight perceived conservatisms associated with the current licensing basis. The licensee stated that the assumptions which provide a basis for the current licensing basis flood elevation of 361 feet could not be exactly reproduced; therefore, the impact on the Annual Exceedance Probability (AEP) with regard to those original assumptions was not explicitly factored into the NRC's final risk significance determination.

The licensee's reevaluated flood modeling assumptions resulted in a PMF elevation of 353.8 feet. The NRC's final significance determination result of Yellow is not based on approval or rejection of the licensee's reevaluated PMF elevation of 353.8 feet, but rather on the overall risk insights provided by the associated analyses. In making the final significance determination, the NRC recognized that precise estimates for extreme flooding events are not available, that there are limitations on the credibility of flood extrapolation approaches, and that there are significant ranges of uncertainty associated with the results in both the PMF elevations and AEP estimates.

The challenges in extrapolating flood frequencies were discussed in a workshop on state-of-the-art probabilistic flood analyses (reference NUREG/CP-0302, "Proceeding of the Workshop on Probabilistic Flood Hazard Assessment (PFHA): Held at the U.S. Nuclear Regulatory Commission Headquarters, Rockville, MD, January 29-31, 2013") for extreme events such as the PMF and were mentioned in the NRC's preliminary significance determination letter. The insights from this workshop reaffirmed the NRC's use of qualitative criteria as prescribed by IMC 0609, Appendix M, to conduct significance determination process (SDP) evaluations involving extreme flooding events.

At the Regulatory Conference and in documents provided to the NRC prior to the Conference, the licensee presented multiple flood evaluation methods, including flow-based and precipitation-based approaches, to estimate the ANO flood hazard. The licensee indicated that the AEP associated with a relevant Probable Maximum Precipitation (PMP) depth of 6.93 inches producing a flood elevation of 354 feet (i.e., all floods exceeding site grade elevation) would have a 95 percent confidence level value of 1.44×10^{-5}/year (or 69,444-year return period) with a best estimate median of 1.15×10^{-6}/year (or 869,565-year return period). In addition, the licensee stated that the PMP precipitation depth of 7.27 inches associated with flooding events exceeding a flood elevation of 356 feet at ANO (i.e., exceeding site grade level by 2 feet) would have a 95 percent confidence level AEP of 1.05×10^{-5}/year (or 95,238-year return period) with a best estimate median AEP of 7.94×10^{-7}/year (or 1,259,445-year return period). The licensee indicated that the use of multiple methods provided additional justification for extrapolation of flood frequencies for use in the SDP. In addition, other assumptions and considerations from the hydrologic and hydraulic modeling used by the licensee were characterized as providing additional conservatism in the insights presented.

As noted above, the licensee used multiple evaluation methods in its analyses to determine the AEP or flood frequency for PMP events that would cause flooding at or above site grade level. Those analyses, as well as other methods that are equally applicable, led the NRC to conclude that flood frequencies greater than 1×10^{-4}/year may be conservative for the ANO site based on available information. By the same token, the NRC concluded that flood frequencies less than $1x10^{-5}$/year (100,000-year or greater return period) could not be established with sufficient confidence in best estimate results for the purposes of this SDP evaluation.

The NRC noted that the licensee made reference to aspects of each methodology presented by the licensee having been used by other Federal agencies as well as in published literature. As discussed in the workshop held at the NRC in January 2013, the NRC has not approved methods for extrapolating the frequency of extreme events such as the PMF. While some state-of-the-art approaches were discussed in this workshop and have been used in certain applications (e.g., such as the stochastic-based modeling of flooding phenomena for specific watersheds as opposed to more extrapolation-focused techniques), the NRC also noted that: (1) the methods presented by the licensee for ANO are extrapolation-based, and therefore still include significant uncertainty (whether accounted for explicitly or implicitly), and (2) the estimates provided are beyond the typical limits of extrapolation considered as credible in the current state-of-the-art methodologies.

For example, the licensee's flow-based extrapolation uses an approach described in Bulletin 17-B, "Guidelines for Determining Flood Flow Frequency" published by the Department of Interior. The applicability of Bulletin 17-B was intended to be limited. This bulletin was designed for applications such as levee and floodplain management, and was not intended for extending estimates to 1-in-10,000 events. It is recognized that the applicability of this method is limited to AEPs in the ranges closer to the available historical record. As stated during the January 2013 workshop held at the NRC, the applicability of such a method was not intended for AEPs in the range of $1x10^{-4}$/year (or 10,000-year return period) or less likely events. Similarly, as discussed in the U.S. Department of Interior, Bureau of Reclamation Report DSO-04-08, "Hydrologic Hazard Curve Estimating Procedures," there is a relationship between the quality and quantity of data available and the limit on credible extrapolation flood estimates. This includes some of the methods used in the licensee's precipitation-based approaches (e.g., L-moments), as well as other methods not included in the ANO estimates (e.g., paleoflood information). Even when combined with optimal information, a limit of $1x10^{-4}$/year (or 10,000-year return period) for credible information is acknowledged. As stated in Bulletin 17-B, with regard to regional precipitation data, "a similar limit [$1x10^{-4}$/year] is imposed because of the difficulty in collecting sufficient station-years of clearly independent precipitation records…" While this bulletin focuses on areas in the Western U.S., the discussions in the workshop held at the NRC in 2013 indicated the challenges described above exist when dealing with limited information, as is the case at ANO. The analyses the licensee presented at the Regulatory Conference attempted to use as much of the available information as possible (e.g., over 3,000 years of equivalent record was added via the L-moments approach), however, without additional stochastic physical modeling or relevant at-site paleoflood data, extrapolation of flood frequencies beyond the level of confidence currently assessed by the community of expert practitioners (10,000 year return period) carries significant uncertainty.

While the consideration of multiple extrapolation approaches and the consistency in the results of each of the precipitation-based analysis methodologies do provide additional confidence that AEPs greater than $1x10^{-4}$/year (10,000 year or less return period) would be overly conservative for consideration in the final significance determination of these findings, the NRC concluded that AEPs of less than $1x10^{-5}$/year (100,000-year or greater return period) could not be established with sufficient certainty for the purposes of this SDP evaluation. The NRC recognizes that additional uncertainty not captured by the extrapolated results could impact the bounding results in this assessment and that any extrapolated estimate may involve uncertainty bounds of several orders of magnitude. For example, the flow-based extrapolations developed by the NRC and licensee indicated an upper bound closer to the $1x10^{-4}$/year threshold.

In summary, the analyses provided by the licensee indicates that, even with a preliminary reevaluated flood hazard analysis (i.e., PMP of 6.93 inches and PMF of 353.8 feet), the resulting 95 percent confidence level AEP does exceed the $1x10^{-5}$/year threshold, and that sufficient justification for reliance on a more precise value is not currently available, as these estimates include several orders of magnitude of uncertainty. The NRC concluded that the information provided supports an SDP approach that considers qualitative attributes to determine the significance of the finding in conjunction with the insights associated with the uncertainty and confidence limits provided by the licensee in the flow-based and precipitation-based analyses.

2. Defense in Depth

   The licensee's presentation categorized some of the recovery actions as defense-in-depth elements. However, the licensee agreed that normal plant equipment and system alignments for reactor coolant system inventory control, reactor core heat removal, and containment pressure control functions would not be available to mitigate flooding events. The licensee did present proposed mitigating actions to recover safety functions for flood levels above plant grade level. Those recovery actions are discussed in Section B below.

3. Reduction in Safety Margin

   As stated in the NRC's preliminary significance determination letter, the current design basis flood elevation is 361 feet. Flood water above plant grade level of 354 feet could result in the loss of all reactor makeup and cooling pumps, potentially leading to core damage without mitigating actions. The licensee stated that safety would be challenged with flood waters above plant grade level and that the revised PMF elevation of 353.8 feet was below the plant grade level. The licensee presented proposed actions to recover safety functions for flood levels above the plant grade level.

4. Effect on Other Equipment

   The licensee acknowledged that failure of the subject flood barriers could result in failure of the emergency feedwater pumps, high pressure injection pumps, spent fuel pool cooling pumps, emergency diesel generators, decay heat removal pumps, and reactor building spray.

5. Degree of Degradation

   The licensee acknowledged that equipment damaged due to submergence in water could not be recovered.

6. Exposure Time; Previous Identification Opportunities

   The licensee acknowledged that the performance deficiency has existed since construction. The only exceptions were a plant modification in 2002 that resulted in unsealed abandoned equipment and inadequate preventive maintenance activities that caused degradation of flooding seals over time. All quantitative assessment considerations were performed using the one-year assessment period limit in the SDP. The licensee acknowledged that previous identification opportunities for the degraded flood barriers had existed.

7. Recovery Actions

   The NRC's preliminary significance determination did not credit alternative mitigating strategies. During the Regulatory Conference, the licensee provided information related to mitigation strategies to protect the turbine building from flooding by using a temporary flood barrier, and recovery actions to maintain or recover reactor core heat removal functions for both units by establishing water injection to the steam generators from either the service water system or portable pumps. The licensee did not provide long-term recovery actions for restoration of the reactor coolant inventory control function, nor the containment pressure control function. The NRC's evaluation of the licensee's proposed mitigation strategies/recovery actions is provided below.

8. Additional Circumstances

   The licensee stated that its revised PMF is below plant grade level and that conservatisms exist in the PMP/PMF estimates to reduce the 95 percent confidence level risk by an order of magnitude. The NRC reviewed the licensee's calculations and presentation related to the PMP/PMF as described in Section A.1, "Bounding Risk Evaluation," above. The NRC also observed that the licensee's risk estimates were based on extrapolations with limited consideration of modeling uncertainty. For estimates of extreme events, information available from the community of experts indicates that considerable modeling uncertainty would be involved. The NRC noted that inclusion of such uncertainty (consideration of which was limited in the licensee's upper bound estimates) would increase the 95 percent confidence level value.

B. EVALUATION OF THE LICENSEE'S PROPOSED MITIGATION AND RECOVERY ACTIONS

During the Regulatory Conference, the licensee presented five mitigation strategies in the event of a postulated flood above plant grade level. The licensee proposed recovery credit based, in part, on human error probabilities derived from the SHARP1 human reliability analysis (HRA) methodology. The NRC noted that the licensee's model reflected human error probabilities assuming typical plant conditions, which are different than plant conditions that may be encountered during a flooding event. The NRC noted that the SHARP1 method did not account for an evaluation of operator diagnostic actions in the absence of procedural guidance, when multiple, competing mitigation strategies/recovery actions are plausible. Based on an evaluation of circumstances under which the operators may be prompted to implement recovery actions, the NRC concluded that failure to diagnose the need to implement recovery actions could be substantially high for a number of the recovery actions.

The NRC recognizes that human reliability analysis methods for evaluating actions under extreme conditions are limited. The NRC used the SPAR-H HRA method (NUREG/CR-6883) to estimate the human error probabilities associated with potential recovery actions. The SPAR-H method provides an estimate that accounts for timeliness, ergonomics, quality of procedures, and stress while diagnosing and performing tasks. The NRC also included insights gained through direct inspection efforts following the Regulatory Conference.

The results of the licensee's AEP analysis presented at the Regulatory Conference suggested that approximately 70 percent of flooding events with water level above site grade of 354 feet would also exceed 356 feet. Based on consideration of these estimates, in addition to corresponding information from the 100,000-year return PMP hazard curve developed by the NRC's analysts as part of the preliminary significance determination, the NRC determined that almost half of above-site-grade level flooding events at ANO would also exceed the 356-foot level. The licensee stated that the implementation of the temporary dam mitigation strategy discussed below would not provide mitigation for a flooding event above 356 feet, and that the implementation of the portable pump mitigating strategy discussed below could be more difficult to accomplish for a flood above 356 feet.

1. <u>Site Preparation for Flooding</u>

During the Regulatory Conference, the licensee presented mitigating actions that could be taken after notification of an impending flood, yet prior to the arrival of flood waters on site. As stated in the NRC's preliminary significance determination letter, the Startup Transformer 02 would be modified before flood waters arrived to permit continued operation and availability of offsite power during the flooding event. In addition, procedural guidance required plant operators to consider moving portable pumps to a staging area in the training center parking lot prior to flood waters arriving onsite, to protect the pumps.

During the Regulatory Conference, the licensee stated that upon notification of an impending flood, actions could be taken to protect the turbine building up to a flood elevation of 356 feet. According to the licensee, those actions would be prompted by a corporate-level severe weather procedure that directs corporate assets to be protected from flooding. The licensee proposed a 30 percent failure probability that the site emergency response organization would implement measures to protect the turbine building from postulated floods up to a flood elevation of 356 feet. For flood levels above 356 feet, the licensee agreed the failure probability would approach 100 percent for these site preparation actions.

The licensee presented pre-flood preparations that included a water-filled temporary dam, sandbagging, concrete barriers, welding steel barriers over doors, and sealing underground penetrations. The NRC determined that the licensee had not verified that the materials were physically available and could be installed before flood waters exceeded the plant grade level. In addition, the dam, sandbagging, and barriers are temporary "equipment" and subject to potential failure mechanisms. For example, experience at other sites shows the dam could be punctured during installation or use, or installed over permeable surfaces (gravel) and rendered ineffective. The NRC also concluded that a corporate-level procedure providing a checklist to indicate that temporary flood barriers should be considered does not provide "clear planning guidance" as described in the preliminary risk determination. Given the non-specific procedural guidance, likely operator mindset that the reactor plant was protected from flooding, and the number of unknown flood deficiencies at ANO, the NRC assigned a high (90 percent) failure probability for the installation of temporary flood barriers. In the context of a sensitivity analysis, the NRC also determined what the SDP result would be with an assumed lower failure probability of 50 percent. The results of this sensitivity analysis are discussed in Section C. No mitigation credit was given for flood levels above 356 feet.

2. <u>Decay Heat Removal Recovery Using Feed to Steam Generators</u>

   The licensee presented information that would indicate that decay heat removal could be maintained by initiating actions to feed the steam generators by either of two methods. First, the service water system could be used to feed the steam generators through the submerged and idled emergency feedwater system pumps, which required opening of service water to emergency feedwater cross-connect valves. Second, an alternative mitigation strategy, portable diesel-driven pump (portable pump) could be used to supply water to the steam generators. Either of these strategies could be performed first, depending on the diagnosis and choices made by the plant operators. The licensee assumed a nominal combined failure probability of five percent for feeding the steam generators using these strategies. After the Regulatory Conference, NRC inspectors identified several problems with these strategies that were not identified by the licensee which complicated the actions and resulted in the NRC's determination that the failure probabilities assumed by the licensee for these strategies were unrealistic.

   a. <u>Unit 2 Service Water System Recovery</u>

      The success of this strategy would require operators to diagnose the need to open service water cross-connect valves to the suction of the emergency feedwater pumps, while the reactor continued to be cooled by the decay heat removal system. Following diagnosis that decay heat removal may be challenged, operators must open the service water supply to emergency feedwater pump suction valves before flooding in the auxiliary building caused a loss of remote operation capability. The NRC determined that adequate time existed for operators to diagnose and align the service water system.

      Operators would not be able to verify decay heat vault flooding alarm accuracy nor actual water level in the decay heat removal vaults because access to the vaults would be blocked by flood waters. Additionally, there is a single annunciator for all three vaults in Unit 2, and therefore, given flooding in the auxiliary building, operators would be unable to confirm if one or multiple vaults were flooding. Though operators would likely recognize that a flood alarm would be associated with water intrusion from the site flooding event, the combination of the inability to validate the alarm, the lack of indications for individual vaults, and the likely belief by operators that the vaults would not flood since the vaults were thought to be watertight, supported the use of poor ergonomics in the SPAR-H model for human reliability analysis.

      While emergency operating procedures address using service water as an alternative suction source for the emergency feedwater system, the entry conditions to use emergency operating procedures would not have been met at the time this action would have been required. In addition, pumping service water through an idle emergency feedwater system had not been proceduralized, and therefore the associated actions had not been demonstrated nor had operators been trained on these actions. The NRC determined that opening of the service water to emergency feedwater cross-tie valves is feasible; however, pre-existing procedures were not available to support diagnosis, the viability of this contingency strategy had not been demonstrated nor had operators trained on it, and the recovery had to be accomplished prior to flooding of the service water valves. Consequently, the NRC determined there was a high (83.5 percent) failure probability to reposition service water valves prior to their submergence.

Furthermore, the operators had to initiate feed to the steam generators with service water via the emergency feedwater system with idle feedwater pumps. The licensee's evaluation indicated that a service water system pressure of 76 psig was available to provide flow through the emergency feedwater system based on the results of a surveillance test conducted while the system was aligned to the emergency cooling pond. After the Regulatory Conference, NRC inspectors determined that the service water system pressure could be 60 psig based on a review of plant data that represented the conditions and system alignment that would exist for an external flooding event. In addition, the NRC identified that Valve 2CV-1460, a backpressure control valve, could fail open upon a loss of control power, which may reduce system pressure by as much as five psig. Valve 2CV-1460 is at 335 feet in the auxiliary building general area and would be submerged during a flooding event. With service water pressure at approximately 55 psig, the system pressure would be lower than that required to overcome the steam generator pressure and static head of the emergency feedwater system. The NRC determined that the proposed mitigation strategy/recovery action may not result in adequate flow to the steam generators without further operator diagnosis and action.

Following the NRC's identification of the possible failure of this proposed mitigation strategy, the licensee provided additional information suggesting that operators could diagnose the system condition and raise service water pressure by starting a third service water pump and isolating the non-safety related, auxiliary cooling water portion of the service water system.

The NRC determined that this recovery action would require a moderately complex diagnosis. Multiple variables would need to be evaluated including service water system alignment, unique system configurations, and pump failures in order to diagnose the lack of adequate flow to the steam generators. The ability to evaluate the service water system configuration could be impacted by flood waters throughout the buildings. No procedures existed to diagnose the need to realign valves to increase system pressure. In addition, the diagnosis would also involve re-evaluation of operator actions that were taken to align service water to emergency feedwater, since those actions did not result in feed to the steam generators as expected.

Restoration of service water pressure to provide for service water flow to the steam generators is feasible, however, the NRC noted that procedures governing this evolution were not available to support diagnosis, the viability of the actions to restore service water system pressure had not been demonstrated or trained on, and the mitigation strategy/recovery actions had to be accomplished before the loss of natural recirculation in the reactor coolant system. Consequently, the NRC determined that there was a 29 percent failure probability for restoring service water pressure such that service water flow to the steam generators could be established. This failure probability also accounted for the dependency of the recovery diagnosis and actions on the preceding initial failure to establish sufficient service water pressure.

In summary, the NRC determined that the use of service water to feed the Unit 2 steam generators to provide for decay heat removal, had a very high failure probability (approaching 100 percent), due to the multiple diagnosis efforts and actions involved, including the diagnosis and recovery from the initial failure to establish service water flow; as well as the lack of, or limited, procedural guidance, and time constraints that would exist. In the context of a sensitivity analysis, the NRC also determined what the SDP result would be with an assumed lower failure probability of 50 percent. The results of this sensitivity analysis are discussed in Section C.

b. Unit 1 Service Water System Recovery

The licensee presented information during the Regulatory Conference that the service water system could be used to feed the Unit 1 steam generators through the submerged and idled emergency feedwater system pumps, similar to the alignment described for Unit 2 above.

The licensee stated that Unit 1 operators would have two hours to diagnose and take action between the time of the first control room alarm notifying operators of water in the decay heat removal vaults, and the time when the service water recovery action would not be available due to submergence of the motor-operated service water to emergency feedwater cross-connect valves. The licensee stated that a second vault alarm would annunciate 1.5 hours before service water valve submergence, providing a second cue. The licensee noted that operators would require approximately one hour to diagnose and take the action to open the service water valves.

Following the Regulatory Conference, NRC inspectors determined that the licensee used assumptions in its decay heat vault flooding analysis that were non-conservative. Specifically, the licensee calculated flows into the vaults assuming empty electrical conduits even though the conduits could be up to 20 percent full of wires. The licensee assumed up to 10 outlets per conduit even though it could be as few as two. The licensee assumed that the conduit high points were at the observed junction boxes even though construction photographs indicated they could be as much as one foot higher than the connection at the junction boxes. The NRC inspectors recalculated the time available between receipt of the decay heat vault alarm and submergence of the service water valves using more realistic assumptions, and determined that the operators would have approximately one hour to diagnose and take action to implement this recovery strategy between the first vault alarm and submergence of the valves. The inspectors determined that the second vault's alarm would annunciate at approximately the same time the service water valves would become submerged, so the operators would have to diagnose the condition with only one vault in an alarm condition. The NRC determined that not enough time existed to diagnose and initiate this service water recovery strategy because with a single vault alarm, operators would have to anticipate both vaults flooding and anticipate that pumping service water through an idled emergency feedwater system would be necessary before decay heat removal failed.

Therefore, due to the time constraints and lack of cues to indicate the challenge to decay heat removal, the NRC assigned a high failure probability (approaching 100 percent) for the use of service water to feed the Unit 1 steam generators to provide for decay heat removal. In the context of a sensitivity analysis, the NRC also determined what the SDP result would be with an assumed lower failure probability of 50 percent. The results of this sensitivity analysis are discussed in Section C.

c. Alternative Mitigation Pump Recovery Strategy

The licensee presented information that an alternative mitigation strategy, portable diesel-driven pump (portable pump) could be used to supply water to the steam generators in Unit 1 and Unit 2. Although operators are trained on using the pump in restoring steam generator levels upon loss of a wide range of plant equipment, the alternative mitigating strategies procedure was not intended for a flooding event.

The licensee's external flooding procedure directed personnel to consider moving the portable pump to higher ground (training center off-site parking lot) prior to flooding onsite to protect the portable pump from flood water. Although contrary to the guidance in this procedure, the NRC considered as a potential action that operators could anticipate the potential for a loss of all core cooling due to flooding and decide to move the pump onto the site, on an elevated platform, such that it was staged and ready if needed as a potential decay heat removal recovery strategy, before significant flood waters arrived onsite. The NRC concluded that it was much more likely the pump would be moved off-site and protected from flooding, until some other plant indication of potential loss of decay heat removal prompted a diagnosis that the portable pump should be deployed, at which point the pump would need to be moved to the site through existing flood waters.

The licensee presented a one-hour timeline for this recovery strategy based on a walkthrough of required actions on dry ground. The NRC determined this did not account for challenges that could be imposed from flooding onsite. The road between the training center and the plant is one foot lower than plant grade level. The NRC noted that electrical equipment on the pump skid could be submerged at flood levels of 355 feet or higher during transportation on the normal trailer. Therefore, the NRC determined that the licensee could likely take several hours to load the pump onto another trailer in order to avoid submerging the pump during transport. The NRC also noted that when the road is covered by flood water, the edges of the road will be obscured to the driver, and the driver may need to use spotters at a slow walking speed. Once the portable pump was at the proper location, several actions would need to be accomplished to align the portable pump to supply water to the steam generators. These would potentially be performed in flood waters and include:

- Connecting the suction of the pump to a fire hydrant while working in flood water
- Standing in flood waters to cut piping (Unit 2)
- Refueling the pump every 12 to 24 hours in flowing flood waters, and

- Potentially isolating transformer fire deluge valves that actuate due to submergence, to maintain fire protection system pressure

While the licensee presented a one-hour time to transport and align the portable pump, the NRC determined that the transport and system alignment time could be greater than seven hours. Although operators are trained on using the pump in restoring steam generator levels upon loss of a wide range of plant equipment, the implementation of these actions is not contained in a procedure used for a flooding event.

Unit 2 Specific Information

In Unit 2, the recovery strategy presented by the licensee would involve pressurizing a startup and blowdown demineralizer header and then using the pressurized header to backfeed into the main feedwater header. Following the Regulatory Conference, NRC inspectors identified that pressure control valves on this demineralizer header could fail open during a flooding scenario due to loss of instrument air pressure. NRC inspectors determined that portable pump flow would be diverted away from the steam generators through the open pressure control valves unless the licensee had closed the valves during demineralizer realignment for full flow secondary cleanup during plant cooldown prior to the arrival of flood water onsite. The decision to perform the demineralizer alignment depended upon available operations resources, the recommendations from chemistry personnel, and the availability of a fresh demineralizer resin load. The NRC assigned a failure probability of 50 percent for the demineralizer realignment. This demineralizer realignment would need to be accomplished in addition to successful portable pump transport and fire protection system alignment for the alternative mitigation pump recovery strategy to be effective. In addition to the factors discussed above, the Unit 2 procedures for implementing this mitigation strategy were incomplete because isolation valves would need to be opened that were not listed, relief valves requiring gags would be under water, and alternate methods to throttle flow were not included.

The NRC determined that use of the alternative mitigation pump recovery strategy for Unit 2 appeared to be feasible, if the shutdown activities resulted in the secondary system being placed in the cleanup configuration. The recovery strategy could be impacted by incomplete procedures and environmental conditions related to flood waters onsite. The NRC assigned a high (85 percent) failure probability for use of the portable pump on Unit 2. In the context of a sensitivity analysis, the NRC also determined what the SDP result would be with an assumed lower failure probability of 37 percent. The results of this sensitivity analysis are discussed in Section C.

Unit 1 Specific Information

With respect to Unit 1, similar challenges existed for the success of the alternative mitigation pump recovery strategy as compared to Unit 2, with two significant exceptions: (1) the flow diversion issues described above were not applicable to Unit 1; and (2) Unit 1 procedures included the necessary valve alignments. The NRC assigned a 37 percent failure probability for use of the portable pump with respect to Unit 1. In the context of a sensitivity analysis, the NRC also determined what the SDP result would be with an assumed lower failure probability of 25 percent. The results of this sensitivity analysis are discussed in Section C.

3. Additional Qualitative Factors Influencing the Risk Assessment

As documented in the NRC's preliminary risk determination letter, the NRC concluded that internal flooding events pose additional risk significance for the flooding-related performance deficiencies. Failure of expansion boots in the Unit 1 and Unit 2 circulating water system is the highest contributor to risk for internal flooding in both Units. The licensee agreed that internal flooding was an important contributor to the overall risk of flooding. The licensee stated that the initiating event frequency for internal flooding for Unit 1 was minimal, and for Unit 2 was 9.03×10^{-5}/year. With respect to internal flooding, the NRC assigned the same recovery credit for mitigation strategies as described in Section B.2 for external flooding, except that the Unit 2 portable pump recovery strategy would not work because the secondary system would not be aligned in the cleanup configuration. The Unit 2 high initiating event frequency for internal flooding coupled with reduced recovery credit was a significant contributor to the final significance determination for Unit 2, in that the risk contribution from internal flooding events alone was Yellow for Unit 2. The NRC agreed that the failure frequency of the circulating water system was lower for Unit 1 than for Unit 2; however, because the circulating water expansion joints in Unit 1 had a metallic component and were not all hard piping as assumed in the licensee's failure probability model, the NRC determined that a more appropriate model of the Unit 1 expansion joints would provide a higher failure frequency for the circulating water system than provided by the licensee. As documented in the NRC's preliminary significance determination letter, the contribution to risk for Unit 1 from internal flooding was qualitatively assessed as Greater-than-Green. This risk contribution would be added to the significance determination results from external flooding events to determine an overall flooding SDP result for Unit 1.

The licensee stated at the Regulatory Conference that it would have enough time to perform an orderly shutdown and cooldown in the event of a flood. The licensee stated that both units' steam generators would be placed in wet layup, which would provide for additional time to respond to, and recover from, a subsequent loss of decay heat removal. However, according to the operations managers for both units, if the licensee anticipates a short outage and chooses to maintain condenser vacuum, the steam generators would not be placed in wet layup. Therefore, Unit 1 operators would have approximately 1.5 hours from a loss of decay heat removal to a loss of natural circulation cooling for the reactor, and Unit 2 operators would have several hours. This is different than the information in the timeline presented by the licensee in the Regulatory Conference. Although the NRC did not explicitly use the shorter timeline associated with the steam generators not being in a wet layup condition, if the NRC had included that assumption in the SDP analysis it would result in additional risk to the qualitative assessment.

The NRC identified that the need to establish and maintain a method of long-term reactor coolant system inventory makeup and control is an important risk consideration that could represent additional risk significance for a flooding event in light of the performance deficiencies. The preliminary significance determination stated that all reactor coolant system makeup pumps were below the postulated flood levels of concern and would fail given a flood at or above the site grade of 354 feet. The licensee presented a strategy of using manual control of the core flood tanks (Unit 1) or safety injection tanks (Unit 2) to maintain sufficient inventory in the reactor coolant system to support adequate core cooling capability for a short period of time (up to 72 hours). The licensee did not present a strategy beyond 72 hours for long-term reactor coolant system inventory control.

C. CONCLUSIONS

Based on its extensive evaluation, including careful consideration of the information provided by the licensee, the NRC determined that no change to the preliminary risk significance determination result of Yellow for both Unit 1 and Unit 2 is warranted.

The licensee used a range of evaluation methods, including flow-based and precipitation-based approaches, to determine the AEP or flood frequency for PMP events that would cause flooding at or above site grade level. These methods are extrapolation-based, and therefore include significant uncertainty, and the resulting estimates provided by the licensee are beyond the typical limits of extrapolation considered credible in the current state-of-the-art methodologies for determining the frequency of extreme events. While the consideration of multiple extrapolation approaches and the consistency in the results of each of the precipitation-based analysis methodologies do provide additional confidence that AEPs greater than $1x10^{-4}$/year (10,000 year or less return period) would be overly conservative for consideration in the final significance determination of these findings, the NRC concluded that AEPs of less than $1x10^{-5}$/year (100,000-year or greater return period) could not be established with sufficient certainty for the purposes of this SDP evaluation.

The NRC concluded that several of the mitigation and recovery strategies proposed by the licensee would likely not have succeeded due to unrecognized system alignment issues that were identified by NRC inspectors. In addition, the NRC concluded that the licensee underestimated the complexity and environmental challenges that would be faced by the operators in diagnosing and implementing these strategies. Consequently, the NRC's final risk determination reflects significantly less mitigation credit than proposed by the licensee.

While the NRC concluded that reliance on a more precise value between the thresholds of $1x10^{-5}$/year to $1x10^{-4}$/year for the AEP or flood frequency of PMP/PMF events cannot be justified, given the credible limits of extrapolation in the current state-of-the-art methodologies for determining the frequency of extreme events, the NRC performed a quantitative analysis using the licensee's 95 percent confidence level AEP of $1.44x10^{-5}$/year as an initiating event frequency. As discussed above, the NRC did not consider AEPs of less than $1x10^{-5}$/year to be credible. Consequently, the NRC concluded that use of the licensee's best estimate value for AEP of $1.15x10^{-6}$/year would not provide meaningful risk insights. Using the AEP value of $1.44x10^{-5}$/year, the NRC then applied what it considered to be appropriate credit for the mitigation and recovery strategies as described in Sections A and B of Enclosure 2. The results for Unit 1 and Unit 2 were as follows:

For Unit 1, after application of the failure probabilities for external flooding mitigation strategies as described in Sections B.1, B.2.b, and B.2.c, the SDP result for Unit 1 was White. In the context of a sensitivity analysis, the NRC applied overly optimistic failure probabilities for external flooding mitigation strategies as described in Sections B.1, B.2.b, and B.2.c, and the SDP result remained White.

For Unit 2, as stated in Section B.3, the risk from internal flooding alone resulted in an SDP result of Yellow. In the context of a sensitivity analysis, the NRC applied an overly optimistic failure probability of 10 percent for the service water mitigation strategy for internal flooding, as well as overly optimistic failure probabilities for external flooding mitigation strategies as described in Sections B.1, B.2.a, and B.2.c. The SDP result for this Unit 2 sensitivity analysis remained Yellow.

Given the current lack of confidence in a definitive approach to establish initiating event frequency best estimates for consideration in extreme flooding events, IMC 0609 Appendix M provides the appropriate method for determining the final significance. Notwithstanding, the quantitative analysis described above was conducted to provide risk insights to the Appendix M qualitative assessment. As described in the NRC's preliminary risk determination letter, Appendix M specifies that a bounding, i.e., worst case, analysis should be conducted using the best available information, followed by the consideration of appropriate qualitative factors in determining the significance of the associated finding. With respect to the bounding analysis, the NRC determined that the upper bound AEP was less than 1×10^{-4}/year, therefore, the upper bound risk assessment per Appendix M is Yellow.

With respect to the consideration of appropriate qualitative factors in determining the significance of the associated finding, the NRC's assessment of those qualitative factors and corresponding results, are described in Section A.1-8. In summary, for Unit 2, the significant additional risk contribution due to internal flooding and limited credit for external flooding mitigation and recovery strategies, results in a final significance determination of Yellow. For Unit 1, the risk profile is less severe than for Unit 2, both in the failure probability of the portable pump mitigation strategy and the contribution from internal flooding. However, based primarily on flood frequency uncertainties and the lack of long-term recovery actions for restoration of the reactor coolant inventory control function and the containment pressure control function, the NRC determined that a final significance determination of Yellow was appropriate for Unit 1.