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RS-03-132

July 17, 2003

U. S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555-0001

Quad Cities Nuclear Power Station, Units 1 and 2
Facility Operating License Nos. DPR-29 and DPR-30
NRC Docket Nos. 50-254 and 50-265

Subject: Response to Request for Additional Information – License Renewal Environmental Report for Quad Cities Nuclear Power Station, Units 1 and 2

References: (1) Letter from J. A. Benjamin (Exelon Generation Company, LLC) to U. S. NRC, "Application for Renewed Operating Licenses," dated January 3, 2003

(2) Letter from Louis L. Wheeler (USNRC) to John Skolds (Exelon Generation Company, LLC), "Request for Additional Information (RAI) Related to the Staff's Review of the License Renewal Environmental Report for the Quad Cities Nuclear Power Station, Unit 1 and 2 (TAC NOS. MB6845 and MB6846)," dated May 23, 2003

Exelon Generation Company, LLC (EGC) is providing the information requested in Reference 2. This additional information is provided to support the NRC's review of the License Renewal Application submitted in Reference 1.

Should you have any questions, please contact Al Fulvio at 610-765-5936.

Respectfully,

Patrick R. Simpson

Patrick R. Simpson
Manager – Licensing
Mid-West Regional Operating Group

Attachments:
Affidavit
Attachment 1: RAI Responses Related to Severe Accident Mitigation Alternatives
Attachment 2: RAI Responses Related to Transmission Lines

A098

cc: Regional Administrator – NRC Region III
NRC Senior Resident Inspector – Quad Cities Nuclear Power Station
Office of Nuclear Facility Safety – Illinois Department of Nuclear Safety

STATE OF ILLINOIS	)	
COUNTY OF DUPAGE	)	
IN THE MATTER OF	)	
EXELON GENERATION COMPANY, LLC	)	**Docket Numbers**
Quad Cities Nuclear Power Station - Units 1 and 2	)	**50-254 and 50-265**

SUBJECT: **Response to Request for Additional Information – License Renewal Environmental Report for Quad Cities Nuclear Power Station, Units 1 and 2**

AFFIDAVIT

I affirm that the content of this transmittal is true and correct to the best of my knowledge, information, and belief.

Patrick R. Simpson
Manager - Licensing
Mid-West Regional Operating Group

Subscribed and sworn to before me, a Notary Public in and

for the State above named, this 17th day of

July, 2003

"OFFICIAL SEAL"
TIMOTHY A. BYAM
COMMISSION EXPIRES 12/04/05

Notary Public

Attachment 1

RAI Responses Related to Severe Accident Mitigation Alternatives

RAI 1

The Severe Accident Mitigation Alternatives (SAMA) analysis is based on the most recent version of the Quad Cities Nuclear Power Station (QCNPS) Probabilistic Safety Assessment (PSA) for internal events, i.e., Revision 02B, which is a modification to the updated individual plant examination (IPE) submittal transmitted to the U.S. Nuclear Regulatory Commission (NRC) in December 1996. Please provide the following information regarding this PSA model:

a. *a summary description of any peer reviews of the Level 1 and Level 2 portions of this PSA beyond the normally-performed internal second checker reviews (e.g., QCNPS BWROG Peer Review, Independent Peer Review),*
b. *a characterization of the findings of these internal and external peer reviews (if any), and the impact of any identified weaknesses on the SAMA identification and evaluation process,*
c. *a breakdown of the internal events core damage frequency (CDF) by major contributors, initiators and accident classes, such as loss of offsite power (LOOP) [both single- and dual-unit], station blackout (SBO) [both single- and dual-unit], transients, anticipated transients without scram (ATWS), loss-of-coolant accident (LOCA), interfacing-systems loss-of-coolant accident (ISLOCA), internal floods, and other,*
d. *a description of the major differences from the updated IPE submittal, including the plant and/or modeling changes that have resulted in the new core damage frequency (CDF), along with the corresponding CDF.*

Response 1(a):

"[Provide] a summary description of any peer reviews of the Level 1 and Level 2 portions of this PSA beyond the normally-performed internal second checker reviews (e.g., QCNPS BWROG Peer Review, Independent Peer Review)[.]"

Two external peer reviews of the 1999 Quad Cities Upgrade PRA were conducted.

<u>NEI/BWROG Peer Review/Certification</u>

Conducted in the fall of 1999, with the report published in February of 2000, this review was performed by a six-member industry team following the latest NEI guidance available at the time. Team members were David Gerlits of Pilgrim, Gerry Kindred of Perry, Kent Sutton of Cooper, Don Vanover of ERIN, Ed Vezey of GE, and S. Visweswaran of GE.

<u>Independent External Review</u>

Robert Schmidt of Scientech conducted a thorough external independent review of every aspect of the QC 1999 model, following a checklist of his own.

Response 1(b):

"[Provide] a characterization of the findings of these internal and external peer reviews (if any), and the impact of any identified weaknesses on the SAMA identification and evaluation process[.]"

NEI/BWROG Peer Review/Certification

The NEI Certification team rated the QC PRA very well. The team specifically noted, "The QUAD CITIES PSA is consistent with other industry PSAs in scope, methods, data usage, and results. The PSA does not have unique PSA features." Of the eleven "elements" evaluated by the team, a Summary Score of "4" was received for Systems Analysis. Summary Scores of "3" were assigned to all other elements. In the words of the review team, "These grades are consistent with a very solid PSA program with no major weaknesses." There were no "A" level Facts & Observations (F&Os). There were a number of "B" level F&Os. The 2002B QC Update resolved all "B" F&Os and a number of "C" F&Os, as well.

Quoting from the Peer Review/Certification report:

"The following is a brief summary overview of the QUAD CITIES PSA Peer Review Certification Process results:

- PSA ELEMENTS: All of the PSA elements identified as part of the peer review were included in the PSA. In terms of the overall assessment of each element, all Level 1 elements were consistently graded as sufficient to support applications risk significant evaluations supported by deterministic insights.

- DOCUMENTATION: The documentation of this PSA is excellent in structure, format, and readability. The quality of the documentation made the review of the QC PSA a much easier task than anticipated, and the provision of a "road map" to lead the review team to appropriate documents was a plus.

- INITIATING EVENTS: The guidance is excellent, and provides a clear roadmap for reproducing the analysis. However, the analysis could benefit from an update with more current plant specific data. The grouped initiators are consistent with the event tree structure and success criteria. Dual unit impacts and support system impacts on front-line systems are also addressed appropriately, but may benefit by the incorporation of a loss of a single DC division initiating event analysis into the model. The plant-specific data are well handled with Bayesian updates of generic prior data. The ISLOCA analysis could benefit from the incorporation of surveillance test interval information into the determination of its frequency. The initiating event analysis is well documented, well founded, and clearly supports risk significant evaluations with deterministic input.

- ACCIDENT SEQUENCE EVALUATION (Event Trees): Excellent guidance has been provided for event tree development and all of the information is well documented. Success criteria are based on a combination of generic and plant-specific thermal hydraulic analyses. Plant-specific analyses are used where they provide the most benefit. Some minor inconsistencies between ATWS success criteria and the text that describes them was noted which could be easily addressed. The event trees not only reflect the thermal hydraulic analysis and success criteria accurately, a lot of thought has gone into modeling the plant procedures. The Team noted some innovation in certain areas of event trees relative to modeling plant EOPs. For instance, modeling Suppression Pool Cooling node early in the event tree and differentiating between early and late SLC injection make the event threes more useful and better reflect the EOPs. The approach selected for L2 analysis is somewhat simplified and this is discussed separately. This simplified approach puts additional burden on the L1 analyst to define the end states (PDS) more accurately. It was concluded that the PDS were extremely well defined such that the conservatism introduced in the L1-L2 interface was kept to a minimum. Accident sequence description is documented extremely well and is an asset. A more accurate approach for L2 analysis would involve transferring the cutsets from L1 to L2 PSA. This should be considered for the future PSA modifications so more realistic Risk-informed decisions can be made. Because the PRA analysts have taken a more innovative approach to modeling event trees, the event tree structure looks a little different from the typical BWR PSAs. It would be beneficial to provide a roadmap to the reader about how the event tree is modeled and why the structure is different. Also, it would be useful to guide the reader on how the station blackout sequences are modeled and how to look for the SBO cutsets. Overall an excellent job. The event trees are well structured, model the plant behavior and operating procedures extremely well and the PDS have been defined in a manner that L1and L2 interface is modeled accurately.

- THERMAL HYDRAULIC ANALYSIS: Very good guidance was provided for the TH analysis. MAAP analyses specifically were well catalogued and documented. MAAP has been used extensively for success criteria and time estimates for operator action. The most recent version of the MAAP has not been used, but the version used is adequate for most PSA purposes. Room heat up calculations have been performed as needed. Some confusion exists in the documentation as to whether RCIC room cooling is needed or not. Room heat up calculations are documented in detail. MAAP calculations are documented very meticulously. There was absolutely no problem in looking up any of calculations. Consider taking more credit for CRD injection in general and containment vent for ATWS sequences. Except for comments on the room cooling, the Team felt that this task was very well done and well documented.

- SYSTEMS ANALYSIS: The system notebooks are well above average. The notebooks capture the process used as well as success criteria, good logic modeling, fault trees, simplified P&IDs, cutsets, etc. Operating experience is not explicitly modeled. All front line systems, support systems, dependencies are well modeled. The vintage of the modeling appear to remain close to the IPE and updated information would be beneficial to the results and remove uncertainty based on time not included. System Model Structure (Fault Trees) are, in most cases, down to the major components level. A simplified system drawing outlining the system boundary is provided and useful. Passive systems that could affect the CDF have been considered and modeled. Models are not used on a system level, which is good. Success criteria are well documented within the system notebooks. More details on spatial dependency should prove useful. Excellent job of integrating the various parts of the PSA program.

- DATA: The guidance provided for data analysis was very detailed and was, for the most part, adequate for reproducing the analysis. The plant specific component data was thorough and well documented, and should be updated to reflect the most recent operating experience. The system and train unavailabilities are based on calculations based on Maintenance Rule data. These unavailabilities need to be brought up to date with the most recent operating experience. The data analysis is particularly well documented and complete, especially in its treatment of the grouping of common cause failure modes. The data analysis for the unique unavailabilities is generally good, and well documented. The treatment of electrical bus, relay common cause failures, and level sensors need to be addressed. The overall process is very well documented and reproducible, particularly in the treatment of common cause groups.

- HRA: The guidance documentation is excellent and provides a clear understanding of the process used. It is consistent with industry practices, and provides sufficient detail for reproducing the analysis. Some screening HEPs are used in the quantification of HEPs. The assessment of plant specific procedures has not been updated for this PSA. The lack of coordination with operating personnel is a flaw in this otherwise excellent HRA. The detailed treatment of human interface dependencies is excellent. The documentation is excellent. There needs to be a complete integration of this analysis with the operating staff, ensuring that plant operating procedures, EOPs, AOPs, and training are consistent with the findings of this analysis. With the exception of the lack of integration with the operating staff, this is an excellent analysis of the human interface with the plant.

- DEPENDENCIES: The dependency matrices are very detailed for front-line to support systems, and support systems to support systems. CCF treatment is good for passive components. Improvement is necessary for active components (e.g. breakers, relays, etc.) for proposed PSA applications such as an extended diesel generator allowed out-of-service time submittal. Documentation of plant walkdowns is necessary to validate assumptions made on spatial dependencies. The fault tree modeling included HI dependencies. The point estimates appeared to be within an acceptable range consistent with industry practices.

- CONTAINMENT PERFORMANCE: - Structural: The containment analysis was based on a realistic comparison to the Peach Bottom analysis. There were areas that differ from the Peach Bottom analysis that were not included. A detailed analysis of the Reactor Building was not performed. The documentation of the ATWS analysis would benefit from explicit discussion of RPV and containment failure criteria.

- CONTAINMENT PERFORMANCE: - Level 1/Level 2 Interface: A simplified approach was developed to support LERF point estimates using multipliers. This LERF estimate may become limiting during future applications, but meets the acceptable approach of Regulatory Guides 1.174 and a.177. There is potential for error in grouping and simplifying Level 1 results. System status and human error information for Level 2 classification is not easily retrieved when using the simplified approach. All known phenomenology is incorporated into the CET structure and includes dynamic failure modes which is considered a strength. Limited to resolution of LERF and non-LERF information, the entire spectrum of performance is not available but within reach using the current framework.

- STRUCTURAL RESPONSE: Standard treatment, and industry evaluation procedures were adapted to QC plant. The adding of excessive LOCA sequences was viewed as beneficial to model. Extensive work to support the fragility curve relies on adapting calculations from representative plants. Reactor building is not credited in the model, but should be considered, when expanding Level 2 beyond LERF. The QC containment was evaluated using point estimate, with no detailed analysis for QC. Need to add detail, 1) include secondary containment effects, 2) update plant specific evaluation of containment only as necessary for applications.

- QUANTIFICATION AND RESULTS INTERPRETATION: The guidance for performing the quantification is thorough and clearly defined. A traceable interface exists between the quantification process, the initiating event analysis, and the success criteria analysis, the supporting system models, human reliability analysis, and the data analysis. The dominant sequences provide a clear understanding of the principal contributors to CDF. The truncation levels used in the analysis are sufficient for determining a realistic estimate of CDF as well as the importance of operator actions, systems, and components in the model. The offsite AC power recovery development is well done. Although not considered a limitation, other substantial recovery analyses were not performed. An uncertainty analysis was not performed. It is recommended that this capability be added to the model and performed. The capability to perform such an analysis may be required for certain risk-informed requests in the future. The PSA results summary clearly reflects the process used, identifies the dominant contributors, and provides a basis that is traceable. The quantification process is well documented, well founded, and clearly supports risk significant evaluations with deterministic input.

- Current PSA LERF value appears to be dominated by Class II and Class IV challenges. This LERF estimate may become limiting during future applications. The end states definitions support the future applications envisioned by the utility. This could enhance the usefulness to support most detailed risk applications regarding containment performance. LERF definitions clearly follow industry standards. Level 1 results are conservatively grouped which will affect usefulness for applications. Additional, specific LERF evaluations will be needed to support applications dealing with Technical Specification / licensing relief. Future consideration should be given to reducing the conditional LERF for Quad Cities, as it is anticipated that LERF may be limiting for most applications. Suggest that the Class 2 sequence results be used as basis for modifying the EAL at QC for this class of accident. In addition, updating the ATWS RPS failure basic events should reduce the Class IV contributions to LERF.

- PSA UPDATE: The PSA Model Update Procedure, NEP-17-04 is a good start at a vision of what a model update should be. The greatest shortcoming of the guidance is that it lacks the working level implementation procedures to make the update happen. The input process as it is written lacks a number of elements to ensure the completeness of the data collection effort needed to update the model. The maintenance and update process as defined is quite adequate; the implementation cannot be assessed because there has not been a complete update. The process should support risk significance evaluations with deterministic input, once the procedure is implemented. The most important elements lacking involve input from the plant, including Operations input for procedures and operator response, and systems engineers for as built and as operated information. There are no formal procedures involving control of the PSA model, and the existing practices do not ensure the level of model control necessary for ensuring model fidelity. The existing procedures cover the maintenance and control of the PSA quantification codes. The update procedure is silent on the need to do uncertainty analyses for PSA model and results update. The reviewers have noted that in order to be successful with risk informed applications in the future, uncertainty needs to be addressed."

This review was done for the 1999 version of the model. With the exception of the uncertainty analysis, all suggestions for improvement were implemented in the QC 2002B PRA update. Plant-specific equipment performance data was carefully gathered. Operator interviews were conducted to improve the HRA. A traditional Level 2 model replaced the simplified Level 2 model. The model control and update process has been defined through formal Risk Management procedures. Other specific suggestions for improvement were incorporated by responding to the Level B Facts & Observations. EGC concluded, for now, that it would address uncertainty on a case-by-case basis, as needed for risk-informed applications.

Because the important findings of the NEI/BWROG Peer Review/Certification were resolved in the 2002B model, the weaknesses identified by the Peer Review/Certification team had no impact on the SAMA identification and evaluation process.

Independent External Review

The independent review by Robert Schmidt was conducted during 1999, with the report published in March of 2000.

Quoting from Mr. Schmidt's report:

> **"OVERALL CONCLUSIONS**
>
> The Quad Cities Updated PSA is a high quality Level I plus LERF PSA. All the technical elements meet or exceed general industry practice. The update process is well documented in analysis notebooks. No deficiencies were found in the analyses that need to be corrected immediately.
>
> While documentation and configuration control of the PSA models are very good and important and valuable steps have been taken to insure that that the integrated software and model are installed and functioning properly at the site, the details of PSA software verification and validation, particularly of the commercial software items making up the code package, could be improved...."

Mr. Schmidt also notes:

> "The present PSA can be utilized for most risk-informed regulatory applications as long as a review is made of the open action items to provide assurance that implementation of the actions recommended will not invalidate the PSA results for the specific application. Use of the model and results to support a request for a change in the current licensing basis by NRC will, however, require that appropriate uncertainty and/or sensitivity analysis be performed."

Twenty-nine of Mr. Schmidt's 177 comments fall into the category of requiring attention at the next update. These include 6 comments related to initiating events, such as providing better justification for not including a loss-of-single-DC-bus initiator, evaluating instrument line break, and investigating possible SCRAM discharge volume LOCA's. 9 comments are related to event trees, such as: evaluating historical IORV's at Quad to determine if an IORV ATWS should be modeled; conducting operator interviews to determine how LPI is prevented from injecting following an ATWS; revising ATWS SORV HEP's to reflect added difficulty associated with SORV. 14 comments deal with modeling of various systems, or data, such as: considering further the impact of keepfill system failure, reconsidering treatment of pre-initiator errors in RHR; investigating maintenance experience with SW system check valves and pumps; correcting the model to eliminate the credit for the cross-connection between EDG 2 And unit 1 buses, when EDG2 is the only successful DG.

According to Mr. Schmidt, 13 model comments should be addressed sometime in the future, such as: investigate the contribution of reference leg flashing to CDF; review locations or DC switchgear and determine if loss of cooling is a problem; revise the HPCI model to explicitly include restart failures and failure to take manual control.

The balance of the Mr. Schmidt's comments either required no further action or involved documentation clarifications.

Mr. Schmidt reviewed the 1999 version of the model and documentation. In the 2002B update, EGC responded to all 29 of the comments Mr. Schmidt recommended treating at the next update, plus the 13 that he recommended be treated some time in the future. They have all been resolved. Most of Mr. Schmidt's recommendations for improving documentation have been implemented as well. EGC has also dealt with his comments concerning software control when it improved EGC software control procedures after the merger that created Exelon.

Because the important findings of Mr. Schmidt's review were resolved in the 2002B model, the weaknesses he identified had no impact on the SAMA identification and evaluation process.

EGC Internal Review Process

Revisions subsequent to the 1999 QC model have been controlled by model revision procedures developed after the formation of Exelon Corporation. Procedure ER-AA-600, "Risk Management," defines the EGC Risk Management Program. That procedure requires training and "certification" requirements for EGC risk management engineers. It requires full-power internal events models to be reasonably representative of the as-built, as-operated plant. T&RM ER-AA-600-1015, "FPIE PRA Model Update" specifies requirements for regular update of full-power internal-events models. It specifies updates at least every three years. It requires consideration of the following, when performing an update:

- design changes
- procedure changes
- Technical Specification changes
- component failure rates
- component maintenance unavailability
- initiating event frequencies
- changes to design-basis calculations
- changes to PRA technology

- industry experience
- site operating experience
- open "UREs"

UREs (Updating Requirements Evaluations) are documents prepared whenever a PRA user finds something in the model or documentation that should be changed. A database of these UREs is kept for each plant. If the subject of a URE is urgent, a formal model change can be done immediately. If not, then UREs are reviewed at the time of a scheduled PRA update. Fire and seismic models are revised only as needed.

T&RM ER-AA-600-1012, "Risk Management Documentation" describes required documentation. As "documentation Level 1," the PRA quantification notebook for each update must receive independent review by an EGC "certified" Risk Management Engineer, as well as approval by the Risk Management Director. A Risk Management Engineer is certified only after satisfying the knowledge and performance requirements of a series of EGC Certification Guides dealing with the various aspects of PRA technology. Other PRA documents, such as the Summary Notebook, the Data Notebook, the Event Tree Notebook, the HRA Notebook, and the various System Notebooks, are "documentation Level 2" and, therefore, require a peer review by an EGC certified Risk Management Engineer.

Therefore, the quality of EGC PRA's is maintained by a proceduralized process for PRA maintenance, and requirements for review of all PRA documentation by Risk Management Engineers qualified to a series of formal PRA Certification Guides.

Response 1(c):

"[Provide] a breakdown of the internal events core damage frequency (CDF) by major contributors, initiators and accident classes, such as loss of offsite power (LOOP) [both single- and dual-unit], station blackout (SBO) [both single- and dual-unit], transients, anticipated transients without scram (ATWS), loss-of-coolant accident (LOCA), interfacing-systems loss-of-coolant accident (ISLOCA), internal floods, and other [contributors]."

The contribution to CDF by each initiator in the 2002B PRA Update is shown in Table 1-1.

Table 1-1
Contribution to CDF by Initiator

Event Name	Basic Event Description	2002 CDF (/yr)	% of 2002 CDF
%TDC	LOSS OF 125VDC BUSES 1 AND 2	7.6E-7	35.0%
%DLOOP	DUAL UNIT LOSS OF OFFSITE POWER	3.7E-7	17.0%
%TSW	LOSS OF SERVICE WATER	3.0E-7	13.9%
%TT	TURBINE TRIP WITH BYPASS	1.2E-7	5.5%
%TBCCW	LOSS OF TBCCW	1.0E-7	4.8%
%S1	MEDIUM LOCA (WATER)	1.0E-7	4.8%
%TIA	LOSS OF INSTRUMENT AIR	6.8E-8	3.2%
%MS	MANUAL SHUTDOWN	6.6E-8	3.0%
%TC	LOSS OF CONDENSER VACUUM	5.4E-8	2.5%
%LOOP	LOSS OF OFFSITE POWER	5.2E-8	2.4%
%A	LARGE LOCA INITIATOR	4.5E-8	2.1%
%TF	LOSS OF FEEDWATER	4.4E-8	2.0%
Other	Other Initiating Events	8.3E-8	3.8%
	Total	2.2E-6	100.0%

The ISLOCA CDF is 2.31E-08/yr., or 1% of the Level 1 CDF.

ATWS is treated as a consequential event, not an initiator. The ATWS contribution is determined by the sum of the F-V importance of the mechanical failure to SCRAM and the electrical failure to SCRAM, which is 8% of the CDF.

SBO is a subset of all LOOP events. The contribution to the SBO event tree endstate (i.e., Class IB) is approximately 3.4E-7/yr, or 15% of the CDF.

Internal floods are not included in the 2002B QC internal events model. However, a separate flooding analysis recently completed yields a flooding CDF of 4.67E-7/yr. If this were added to the above internal events CDF, then the flooding contribution would be 18%. The updated flooding analysis developed some insights for plant improvement, but none of them represent major weaknesses. The overwhelming majority of flooding scenarios involve loss of decay heat removal, and they do not represent scenarios significantly different than those in the internal events model. Therefore, the flooding study would not be a source of significant additional SAMA candidates. The SAMAs evaluated do include a number of SAMAs related to flooding. Given the size of the flooding CDF, it is not likely that flooding benefits from Phase II SAMA candidates would change any conclusions about the SAMAs. Furthermore, possible benefits to flooding scenarios are covered by the sensitivity study in response to RAI #7.

Response 1(d):

"[Provide] a description of the major differences from the updated IPE submittal, including the plant and/or modeling changes that have resulted in the new core damage frequency (CDF), along with the corresponding CDF."

<u>Plant Changes since Updated IPE Submittal</u>

- Extended Power Uprate
- EOP and miscellaneous other procedure Improvements
- Significant reduction in number of SCRAM's and significant improvement in equipment reliability and availability.

As noted in the EPU submittal, the changes to the plant for extended power uprate are:

MECHANICAL

- New High Pressure Turbine and modified auxiliaries (EHC)
- Rebuilt Crossaround Relief Valves
- Modified Feedwater Heater drain line valves to handle increased flow
- Condenser staking to mitigate increased vibration
- Additional condensate demineralizer unit.
- Potential upgraded Steam Jet Air Ejectors (alternative is to run both SJAE trains during hottest weather).
- Potential pipe support modifications (torus attached piping will have increased thermal loads).
- The normal operating number of feedwater pumps will be increased from the two (2) for the current power level to three (3) for the EPU.
- The normal operating number of condensate pumps will be increased from the three (3) for the current power level to four (4) for the EPU.

ELECTRICAL/I&C

- NSSS Setpoint changes (APRM flow biased scram and rod block, Main Steam Line high flow isolation, turbine first stage pressure reactor trip bypass).

- Bracing of 4 kV Non-safety switchgear and/or breaker modifications to upgrade short circuit rating.
- Condensate pump trip on LOCA signal to prevent undervoltage on 4kV Busses 14-24 (assumes offsite power available). This modification will prevent load shedding of non-safety related equipment on those busses.
- Recirculation runback on loss of one Reactor Feed Pump or one Condensate Pump (EPU requires running 3 RFPs and 4 CD/CB pumps to attain full power).
- Replacing Main Steam flow switches to span uprated steam flow.
- Transmission and Distribution (T&D) modifications for protective relaying in switchyard.

PRA Changes since Updated IPE Submittal

1999

- Conversion from support-state methodology to single-top fault tree, including revision of all event trees.
- Simplified Level 2 model in the style of NUREG/CR-6595
- Reduced transient frequency based on both plant specific and generic data (i.e., Bayesian update)
- Revised offsite AC power recovery
- Revised HRA, especially to include dependent operator actions, and revised CCF data
- Increased detail in loss of DC bus initiator
- Complete revision of the ATWS event trees, to make them consistent with standard BWR practice. (This is based on BWROG/GE calculations and represents the best estimate plant response to failure-to-SCRAM events. This increased the ATWS contribution.)

2002

- Extended Power Uprate (EPU) plant configuration and MAAP 4.0.4 analysis
- Revised human reliability analysis (HRA) based on the most recent operator interviews and comments of Site Risk Management Engineer
- Completed URE, OPEX, and NON review efforts
- Maintenance unavailability data based on the most recent plant operating experience
- Bayesian updated initiating event frequencies utilizing Quad Cities most recent operating experience

- Individual component random failure probabilities Bayesian updated (as applicable) based upon the most recent plant specific data and the most current generic sources
- Common cause failure (CCF) calculations revised to incorporate the updated individual random basic event probabilities and the most up to date Multiple Greek Letter (MGL) parameters from NUREG/CR-5497 and NUREG/CR-5485
- Revised LOOP/DLOOP analysis for initiating event frequencies and non-recovery probabilities based upon a Midwest regional data filtering approach
- Revised DC distribution system CCF modeling (CCF events set to zero) to prevent double counting
- Revised mechanical and electrical ATWS probabilities, based on information in NUREG/CR-5500. (This lowered the ATWS contribution, compared to the 1999 upgrade.)
- Replacement of the simplified Level 2 model with a full Level 2 model
- Response to Quad Cities BWROG Peer Review comments using the NEI PRA Peer Review Process (NEI 00-02)
- Response to additional independent Peer Review Comments
- Other open item comments from the review of the 1999 draft model
- Credit for repair/recovery of RHR for long term loss of DHR events

As noted in the EPU submittal, the changes to the PRA success criteria for extended power uprate are:

- The RPV depressurization success criteria changed from requiring 1 ERV/SRV to 2 ERVs/SRVs
- The number of SVs/SRVs/ERVs required to open for overpressure protection under failure to scram conditions increased from 11 of 13 to 12 of 13.

The additional principal EPU changes that affected the Level 1 CDF included the following:

- Changes in the Turbine Trip initiating event frequency
- Changes in the SORV probability
- Reduction in time available for operator action causes increase in calculated human error probabilities (HEPs)

The abbreviation "URE" is explained in the answer to RAI #1b. OPEX and NON's are systems that EGC uses to disseminate lessons from nuclear operating experience outside EGC and within EGC. The 2002B model included responses to 57 URE's, covering a variety of topics. No assessment was made of the CDF impact of URE's.

The changes to EOP's and other procedures involve numerous items that are reflected in the revised operator interviews and in the revised HRA results.

It is not possible to determine the CDF change associated with each one of the above model changes. However, a summary of the total calculated CDF for each of the relevant models is provided in Table 1-2.

Table 1-2
Quad Cities CDF History

Model	Date	CDF (Per Yr)
• IPE	12/93	1.2E-06/yr
• Modified IPE	8/96	2.2E-06/yr
• Updated IPE	12/96	2.2E-06/yr
• Conversion/Update (1998 – 99 Update)	4/99	4.6E-06/yr
• Update Revision 02A	4/02	3.9E-06/yr
• Revision 02B	5/02	2.2E-06/yr

RAI 2

The CDF cited and used in the SAMA analysis is based on the risk profile for internal events at QCNPS Unit 1. Please provide the internal events CDF for Unit 2, and a discussion of the reasons for any differences from Unit 1. Discuss the impact on the SAMA analysis, including the impacts of external events, and results if the analysis were based on Unit 2 rather than Unit 1.

Response (2):

Internal Events

Unit 2 CDF

The Unit 2 internal events CDF is identical to that of Unit 1: 2.2E-06/yr.

Unit 2 Differences from Unit 1

There are several minor differences in plant configuration related to the internal events model.

- SSMP SYSTEM. There is an asymmetry in that the normal/preferred supply to Bus 31 for SSMP power is from Unit 1 (AC and DC) and the Unit 2 supply is the alternate (AC and DC). The power realignment for both AC and DC is manual and requires operator intervention. The Unit 2 PRA has Unit-2-specific logic modules for the power supplies to Bus 31 (AC and DC) to account for the preferred (non-symmetric) alignment to Unit 1.

- ADS SYSTEM. Unit 2 has one additional pressure control valve (PCV) in the air supply to each of the PCVs 1(2)-4722A and 1(2)-4722B (supply to Target Rock ADS valve 203-3A). These PCVs rely on the air system for motive power and require no other support systems. The Unit 2 model has a Unit-2-specific logic module for the air supply to the Target Rock ADS valve (2-0203-3A). In addition, the Unit 1 ADS system is comprised of four Electromatic Relief Valves (ERVs) and one Target Rock SRV. On Unit 2, Target Rock PORV's replaced the four ERVs in 1995. However, since the same generic data is used for these as for the Electromatics, this has no effect on the PRA model.

- RHRSW SYSTEM. The power supply for MOV 1001-187A is not symmetric. The Unit 1 valve is powered from MCC 18-1A and the equivalent Unit 2 valve is powered from MCC 28-1B. Since only spurious operation of this valve is modeled, there is no power dependency modeled, and no model changes were required.

- INSTRUMENT AIR SYSTEM. There are three asymmetries associated with the instrument air system. First, there is no equivalent Unit 2 component for the 1B instrument air receiver. Therefore, these failures are eliminated from the Unit 2 model. Second, there are three service air compressors at Quad (1A, 1B, and 2), and their output is always cross-tied. Only two of three Service Air Compressors (1A and 1B) are credited in the Unit 1 model, and they are powered from Unit 1. In order to take credit for two SACs for the Unit 2 PRA model, the 1B compressor is credited in the Unit 2 model. To ensure the correct power supply was identified in the Unit 2 quantification, a dependency was inserted into the logic. Finally, the swing IAC is powered only from Unit 1 (MCC 18).

- ATWS LOGIC POWER. Power to the Unit 1, Div 1 ARI/RPT logic is from 125 VDC Reactor Building Distribution Panel #1 (ckt. #15). Power to Unit 1, Div 2 ARI/RPT logic is from 125 VDC Turbine Building Bus 1B-1(ckt. #32). Power for the Unit 2, Div 1 ARI/RPT logic is from 125 VDC Turbine Building Main Bus 2A-1 (ckt. #4). Power to Unit 2 Div 2 ARI/RPT logic is from 125VDC Turbine Building Bus 2B-1 (ckt. #32). This identifies a minor asymmetry in the Div 1 ARI/RPT power supplies. Turbine Building Main 125VDC Bus 1A(2A) supplies the Div 1 power supplies for both units. However, each Unit's Div 1 ATWS logic is powered from different sub panels. Unit 1 Div 1 ATWS logic is powered from RB Distribution Panel #1 which is fed by Turbine Building Main Bus 1A. Unit 2 Div 1 ATWS logic is powered from Turbine Building Main 125VDC Bus 2A-1 which is fed by Turbine Building Main 125VDC Bus 2A. This is resolved by adding the failures of Bus 2A-1 and its feed breaker to supply ARI DIV 1 control power (CKT BKR 8).

The Unit 2 model uses the same event trees and reliability database as the Unit 1 model. While these differences do appear in low-frequency cutsets, the effects of the fault tree differences are small enough that they do not affect the total internal events CDF. Therefore, the differences do not affect the SAMA analyses for internal events.

External Events

Unit 2 Fire CDF

The fire CDF for Unit 2 as reported in the IPEEE is 7.1E-05/yr., compared to a Unit 1 fire CDF of 6.6E-05/yr.

Fire-Related Unit 2 Differences from Unit 1

Cable routing is not identical for Unit 1 and Unit 2. Two notable asymmetries in the risk profile result. The risk contribution from reactor feed pump fires in Unit 2 is approximately 10% higher than the corresponding contribution from Unit 1. This is because of the specific cable routing of the power supply circuit to MCC 29-2 in Unit 2, which is challenged by postulated Unit 2 RFP fires. The equivalent MCC in Unit 1 (MCC 19-2) is not exposed to such a challenge. The Unit 2 results also show a 4% risk contribution from a postulated air compressor fire because of the proximity of cable trays containing critical circuits for Unit 2 HPCI, for SSMP, and for one train each of Unit 2 CS and RHR. Such exposure does not exist in the Unit 1 analysis.

Rerouting key Unit 2 cables to correspond to the Unit 1 routing is a considerable project. Given the conservatisms and uncertainties in the fire analysis, and given that the maximum possible benefit would be a 7% reduction in Unit 2 fire CDF, this rerouting was not pursued as a candidate SAMA. These differences in fire risk profile are not large enough to affect the analysis for other SAMA's.

Seismic-Related Unit 2 Differences from Unit 1

With modifications to each unit in response to the Seismic Margins Analysis, there is no significant difference in seismic vulnerabilities between the two units.

RAI 3

In the Extended Power Uprate (EPU) Amendment application, Exelon indicates that the Level 2 analysis is based on NUREG/CR-6595. However, there is no such indication in the SAMA portion of the Environmental Report (ER). Based on the above, please provide a description of the following:

a. the changes in the Level 2 methodology since the updated IPE submittal, including major modeling assumptions, containment event tree (CET) structure, binning of end states.

b. the methodology and criteria for binning CET endstates into release categories used in the Level 3 analysis. Include the definitions of the release characteristics listed in Column 2 of Table 4-5.

c. each release (consequence) category used in the Level 3 analysis (as listed in Column 1 of Table 4-5), the specific source terms used to represent each release category, and a containment matrix describing the mapping of Level 1 results (plant damage state frequencies) into the various release categories.

Response 3(a):

"[Provide] the changes in the Level 2 methodology since the updated IPE submittal, including major modeling assumptions, containment event tree (CET) structure, binning of end states[.]"

The IPE, modified IPE, and updated IPE employed what some would call a simplistic Level 2 methodology. Many accident progression phenomena or failure modes were eliminated from consideration, based on experiments, MAAP calculations, or judgments concerning the likelihood of various phenomena. Core damage end states were coded for sequence characteristics that would affect the remaining phenomena affecting containment performance. Based on those characteristics, it was determined in what time range the vessel would fail, whether the pedestal area was dry or wet, whether containment sprays were operating, whether liner melt-through was likely, and whether containment vent was operated. Based on this information, it was determined which core damage end states resulted in containment failure, and which resulted in LERF.

Because of the limitations of the IPE Level 2 model, the model was revised for the 1999 QC PRA Upgrade. It was decided to use a simplified LERF model in the style of NUREG/CR-6595. The 1999 QC PRA was used for the Extended Power Uprate (EPU) submittal.

The submittal for License Renewal required Level 3 calculations. Therefore, EGC decided to develop a full Level 2 PRA model for Quad Cities that meets standard industry practices. The full Level 2 model was used for the License Renewal analyses, and that model also has now been incorporated in the 2002 QC PRA model. It is also the basis for LERF calculations for risk assessment.

A brief summary of the current Level 2 model compared to the 1999 Level 2 model that was used for the EPU submittal follows:

- No changes in modeling assumptions
- CET structure has been enhanced to include more top event nodes
- Old CET had LERF and non-LERF end states whereas the updated model has several release category bins (see Responses 3(b) and 3(c))

Response 3(b):

"[Provide] the methodology and criteria for binning CET endstates into release categories used in the Level 3 analysis. Include the definitions of the release characteristics listed in Column 2 of Table 4-5."

Each CET end state can be associated with a radionuclide source term bin, which covers a spectrum of similar potential scenarios and timing. Theoretically, it would be desirable in determining the point estimates of risk to evaluate the source terms for each sequence of each accident plant damage state. However, for purposes of risk presentation, the CET end states can also be characterized in such a manner as to combine similar "consequence impact" sequences within a CET end state.

The discrete nature of the radionuclide release categories means that the severe accident spectrum is divided up into bins, which then represent a group of severe accidents that have similar characteristics. These characteristics would imply similar public health consequences. It has been found in the past that the public health consequences are affected by a large number of governing features. The following portrays the radionuclide release category characterization used for Quad Cities.

Radionuclide Release Categories (CET End States)

The spectrum of possible radionuclide release scenarios is represented by a discrete set of categories or bins. The end states of the containment and phenomenological event sequences may be characterized according to certain key quantitative attributes that affect offsite consequences. These attributes include two important factors:

- Timing (e.g., early or late releases); and,
- Total quantity of fission products released.

Therefore, the containment event tree end states represent the source term magnitude and relative timing of the radionuclide release. The number of categories used for Quad Cities (i.e., 13) in the source term characterization offers a level of discrimination similar to that included in numerous published PRAs.

Timing Bins

Three timing categories are used, as follows:

- Early (E) — Less than time when evacuation is effective
- Intermediate (I) — Greater than or equal to Early, but less than 24 hours
- Late (L) — Greater than or equal to 24 hours.

The definition of the categories is based upon past experience concerning offsite accident response:

- Early is conservatively assumed to include cases in which minimal offsite protective measures have been observed to be performed in non-nuclear accidents.
- Intermediate is a time frame in which much of the offsite nuclear plant protective measures can be assured to be accomplished.
- Late (>24 hours) are times at which the offsite measures can be assumed to be fully effective.

Radionuclide Release Magnitude Bins

The assessment of plant response under postulated severe accident scenarios is a complex integrated evaluation. The primary and secondary containment building responses are sensitive to pressures, temperatures, flows, and event timings. These parameters also affect the operator action timings, the radionuclide release timings, and the mitigating system performance assessments. Therefore, the proper plant specific characterization of the severe accident progression is important to the realistic representation of the plant and highly desirable for the Level 2 assessment. These deterministic calculations provide the following information:

- The pressures and temperatures for various accident scenarios in the RPV, the drywell, the wetwell, and the reactor building;
- The times to reach these pressures and temperatures which is key to the assessment of recovery; (The time windows available for recovery actions must be estimated.)
- The source term magnitude and timing.

Five severity classifications associated with volatile or particulate releases are defined as follows:

- High (H) - A radionuclide release of sufficient magnitude to have the potential to cause prompt fatalities.

- Medium or Moderate (M) - A radionuclide release of sufficient magnitude to cause near-term health effects.
- Low (L) - A radionuclide release with the potential for latent health effects.
- Low-Low (LL) - A radionuclide release with undetectable or minor health effects.
- Negligible (OK) - A radionuclide release that is less than or equal to the containment design base leakage.

A relationship was then developed with the five release severity categories. The results of this partitioning are shown in Table 3-1.

Table 3-1
Release Severity Categorization

Release Severity	Fraction of Released CsI Fission Products
High	greater than 10%
Medium/Moderate	1 to 10%
Low	0.1 to 1.0%
Low-Low	less than 0.1%
Negligible	much less than 0.1%

The resulting definitions of the radionuclide release end states are summarized in Table 3-2. The combinations of severity and timing classifications results in one OK release category and 12 other release categories of varying times and magnitudes. These 12 other release categories are shown in Table 3-3. These are the dominant release categories shown in column 2 of Table 4-5 of the Environmental Report.

Table 3-2
Release Severity And Timing Classification Scheme

Release Severity		Release Timing	
Classification Category	Cs Iodide % Release	Classification Category	Time of Initial Release[1] Relative to Time for General Emergency Declaration
High (H)	Greater than 10	Late (L)	Greater than 24 hours
Medium or Moderate (M)	1 to 10	Intermediate (I)	5 to 24 hours
Low (L)	0.1 to 1	Early (E)	Less than 5 hours
Low-low (LL)	Less than 0.1		
No iodine (OK)	0		

(1) The conditions dictating a General Emergency are used as the surrogate for the time when EALs are exceeded, which in turn is used as the relative time to measure when the release occurs.

Table 3-3
Quad Cities Release Categories

Time of Release	Magnitude of Release			
	H	M	L	LL
E	H/E	M/E	L/E	LL/E
I	H/I	M/I	L/I	LL/I
L	H/L	M/L	L/L	LL/L

Response 3(c):

"[Provide] each release (consequence) category used in the Level 3 analysis (as listed in Column 1 of Table 4-5), the specific source terms used to represent each release category, and a containment matrix describing the mapping of Level 1 results (plant damage state frequencies) into the various release categories."

Source Terms used to Represent each Release Category

As requested, Table 3-4 provides a list of the source terms associated with each of the release categories as listed in Column 1 of Table 4-5 of the ER.

Table 3-4
Source Terms Associated with Each Release Category

	Release Category[1,2]									
	L2-1	L2-2	L2-3	L2-4	L2-5	L2-6	L2-7	L2-8	L2-9	L2-10
MAAP Run	QC0053	QC0082	NA	QC0085	QC0061	NA	QC0057	QC0058	QC0070	QC0074
Time after Scram when General Emergency is declared	60 min	15 hr	NA	55 min	15 hr	NA	45 min	15 hr	20 min	60 min
Fission Product Group:										
1) Noble										
Total Release % at 36 Hours	94	100	NA	100	100	NA	86	100	100	0.31
Start of Release (hr)	4.4 hr	51.4 hr	NA	55 min	39.3 hr	NA	5.7 hr	25.9 hr	17 min	3.0 hr
End of Release (hr)	4.4 hr	60 hr	NA	4 hr	39.3 hr	NA	5.7 hr	25.9 hr	1 hr	36.0 hr
2) CsI										
Total Release % at 36 Hours	28	33	NA	8.4	3.6	NA	1	0.14	96	2.00E-04
Start of Release (hr)	4.4 hr	60.7 hr	NA	55 min	39.3 hr	NA	5.7 hr	30.0 hr	17 min	3.0 hr
End of Release (hr)	4.4 hr	60.7 hr	NA	2 hr	48.0 hr	NA	10.0 hr	36.0 hr	1.0 hr	6.0 hr
3) TeO2										
Total Release % at 36 Hours	16	12	NA	6.7	0.76	NA	0.28	0.26	77	8.50E-06
Start of Release (hr)	4.4 hr	60.7 hr	NA	55 min	39.3 hr	NA	5.7 hr	32.0 hr	17 min	3.0 hr
End of Release (hr)	9.0 hr	65.0 hr	NA	2 hr	48.0 hr	NA	5.7 hr	36.0 hr	1.0 hr	6.0 hr
4) SrO										
Total Release % at 36 Hours	1.9	2	NA	2.7	0.41	NA	3.2	0.99	4.2	4.90E-05
Start of Release (hr)	4.4 hr	60.7 hr	NA	7.2 hr	60.1 hr	NA	5.7 hr	32.0 hr	17 min	6.0 hr
End of Release (hr)	7.0 hr	65.0 hr	NA	9.0 hr	65.0 hr	NA	5.7 hr	36.0 hr	1.0 hr	6.0 hr
5) MoO2										
Total Release % at 36 Hours	3.00E-04	8.40E-04	NA	0.15	6.50E-03	NA	1.70E-04	3.10E-07	2.2	1.80E-07
Start of Release (hr)	4.4 hr	60.7 hr	NA	55 min	39.3 hr	NA	5.7 hr	25.9 hr	17 min	3.0 hr
End of Release (hr)	4.4 hr	60.7 hr	NA	6.0 hr	39.3 hr	NA	5.7 hr	25.9 hr	1.0 hr	6.0 hr
6) CsOH										
Total Release % at 36 Hours	20	20	NA	7.8	1	NA	0.89	0.11	74	1.10E-04
Start of Release (hr)	4.4 hr	60.7 hr	NA	55 min	39.3 hr	NA	5.7 hr	32.0 hr	17 min	3.0 hr
End of Release (hr)	10.0 hr	70.0 hr	NA	2 hr	48.0 hr	NA	5.7 hr	36.0 hr	1.0 hr	6.0 hr

Table 3-4
Source Terms Associated with Each Release Category

	Release Category(1,2)									
	L2-1	L2-2	L2-3	L2-4	L2-5	L2-6	L2-7	L2-8	L2-9	L2-10
MAAP Run	QC0053	QC0082	NA	QC0085	QC0061	NA	QC0057	QC0058	QC0070	QC0074
Time after Scram when General Emergency is declared	60 min	15 hr	NA	55 min	15 hr	NA	45 min	15 hr	20 min	60 min
Fission Product Group:										
7) BaO										
Total Release % at 36 Hours	0.83	0.87	NA	1.4	0.19	NA	1.4	0.43	4.7	2.00E-05
Start of Release (hr)	4.4 hr	60.7 hr	NA	7.2 hr	60.1 hr	NA	5.7 hr	32.0 hr	17 min	6.0 hr
End of Release (hr)	7.0 hr	65.0 hr	NA	9.0 hr	65.0 hr	NA	5.7 hr	36.0 hr	6.0 hr	6.0 hr
8) La2O3										
Total Release % at 36 Hours	0.23	0.25	NA	0.43	3.70E-02	NA	0.5	0.02	0.58	9.00E-06
Start of Release (hr)	4.4 hr	60.7 hr	NA	7.2 hr	60.1 hr	NA	5.7 hr	32.0 hr	17 min	6.0 hr
End of Release (hr)	7.0 hr	60.7 hr	NA	7.2 hr	65.0 hr	NA	5.7 hr	36.0 hr	6.0 hr	6.0 hr
9) CeO2										
Total Release % at 36 Hours	1.4	1.5	NA	1.9	0.27	NA	1.6	0.19	1.8	2.30E-05
Start of Release (hr)	4.4 hr	60.7 hr	NA	7.2 hr	60.1 hr	NA	5.7 hr	32.0 hr	5.5 hr	6.0 hr
End of Release (hr)	7.0 hr	60.7 hr	NA	7.2 hr	65.0 hr	NA	5.7 hr	36.0 hr	8.0 hr	6.0 hr
10) Sb										
Total Release % at 36 Hours	44	24	NA	24	6.8	NA	20	1.5	75	6.90E-04
Start of Release (hr)	4.4 hr	60.7 hr	NA	55 min	60.1 hr	NA	5.7 hr	32.0 hr	17 min	3.0 hr
End of Release (hr)	14.0 hr	70.0 hr	NA	10 hr	72.0 hr	NA	5.7 hr	36.0 hr	1.0 hr	6.0 hr
11) Te2										
Total Release % at 36 Hours	0.77	0.83	NA	0.21	5.60E-02	NA	0.41	0.17	0.28	2.40E-05
Start of Release (hr)	4.4 hr	60.7 hr	NA	7.2 hr	60.1 hr	NA	5.7 hr	32.0 hr	5.5 hr	6.0 hr
End of Release (hr)	14.0 hr	60.7 hr	NA	7.2 hr	72.0 hr	NA	5.7 hr	36.0 hr	5.5 hr	6.0 hr
12) UO2										
Total Release % at 36 Hours	7.00E-03	7.00E-03	NA	1.00E-02	1.20E-03	NA	1.20E-02	6.00E-04	1.30E-02	2.20E-07
Start of Release (hr)	4.4 hr	60.7 hr	NA	7.2 hr	60.1 hr	NA	5.7 hr	32.0 hr	5.5 hr	6.0 hr
End of Release (hr)	6.0 hr	60.7 hr	NA	7.2 hr	72.0 hr	NA	5.7 hr	36.0 hr	5.5 hr	6.0 hr

(1) Puff releases are denoted in the table by those entries with equivalent start and end times.

(2) All cases run for 36 hrs. except QC0082 and QC0061 run for 72 hrs.

Mapping of Level 1 Results into the Various Release Categories

One link between the Level 1 PSA accident sequences and the Containment Event Tree occurs in the definition of the Level 1 end states. The definition of the end states are developed to transfer the maximum amount of information regarding the accident sequence characteristics to the CET assessment. What follows summarizes the link between Level 1 end states and the entry condition to the CET such that a mapping of the Level 1 results into the various release categories can be provided.

A broad spectrum of accident sequences have been postulated that could lead to core damage and potentially challenge containment. The Quad Cities Level 1 PSA has calculated the frequency of those accident sequences that contribute to the core damage frequency for Quad Cities using system oriented (systemic) event trees. Each of these sequences may result in different challenges to containment. However, many of these challenges to containment have similarities in their functional failure characteristics. This has been confirmed in individual BWR PRAs including NUREG-1150. The result is that these studies have categorized these containment challenges into a finite, discrete group of accident sequence bins, which have similar functional failures.

As pointed out in past BWR PRAs, different portions of the spectrum of postulated core damage accidents represent substantially different challenges to the containment depending upon the system failures and phenomena that have contributed to the sequence. Therefore, the containment event tree response must be capable of reflecting the entire spectrum of challenges to ensure that the following are explicitly incorporated:

- System failures in the Level 1 evaluation (including support systems)
- Phenomenological interaction due to the type of core melt progression
- RPV conditions
    - Pressures
    - Decay heat level
- Containment conditions
- Timing of the sequence of events (i.e., core damage and containment failure (if applicable)).

Core Damage Functional Classes

An event sequence classification into five accident sequence functional classes can be performed using the functional events as a basis for selection of end states. The description of functional classes is presented here to introduce the terminology to be used in characterizing the basic types of challenges to containment. The reactor pressure vessel condition and containment condition for each of these classes at the time of initial core damage is noted in Table 3-5.

Table 3-5
Core Damage Functional Classes (from the Level 1 Analysis)

Core Damage Functional Class	RPV Condition	Containment Condition
I	Loss of effective coolant inventory (includes high and low pressure inventory losses)	Intact
II	Loss of effective containment pressure control, e.g., heat removal	Breached or Intact
III	LOCA with loss of effective coolant inventory makeup	Intact
IV	Failure of effective reactivity control	Breached or Intact
V	LOCA outside containment	Breached (bypassed)

In assessing the ability of the containment and other plant systems to prevent or mitigate radionuclide release, it is desirable to further subdivide these general functional categories. In the second level binning process, the similar accident sequences grouped within each accident functional class are further discriminated into subclasses such that the potential for system recovery can be modeled. The interdependencies that exist between plant system operation and the core melt and radionuclide release phenomena are represented in the release frequencies through the binning process involving these subclasses, as shown in past PRAs and PRA reviews. The binning process, which consolidates information from the systems' evaluation of accident sequences leading to core damage in preparation for transfer to the containment-source term evaluation, involves the identification of 18 classes and subclasses of accident sequence types. Table 3-6 provides a description of the possible subclasses used in the Quad Cities analysis.

The Accident Class designators and subclasses listed in Table 3-6 represent the core damage endstate categories from the Level 1 analysis that are grouped together as entry conditions for the Level 2 analysis. Each of the subclasses is then represented by a series of Containment Event Trees (CETs) to determine the Release Categorization for each of the accident scenarios. As such, the end states from the Level 2 analysis are assigned to one of the Release Categories noted in Table 3-3 as part of Response 3(b). The characterization of the Level 2 results (i.e., as H/E, M/I, etc., or Class V or OK) was then used to determine the frequency of the associated Consequence Category shown in Table 4-5 of the ER. Note that in this fashion, the Level 1 results are not directly linked to a release category, but rather the Level 2 endstate results based on the sum of all of the Release Category frequencies comprise the Consequence Category for each Phase II SAMA considered.

Table 3-6
Summary of the Core Damage Accident Sequence Subclasses

Accident Class Designator	Subclass	Definition	WASH-1400 Designator Example
Class I	A	Accident sequences involving loss of inventory makeup in which the reactor pressure remains high.	TQUX
	B	Accident sequences involving a station blackout and loss of coolant inventory makeup.	T_EQUV
	C	Accident sequences involving a loss of coolant inventory induced by an ATWS sequence with containment intact.	$T_T'C_MQU$
	D	Accident sequences involving a loss of coolant inventory makeup in which reactor pressure has been successfully reduced to 200 psi.; i.e., accident sequences initiated by common mode failures disabling multiple systems (ECCS) leading to loss of coolant inventory makeup.	TQUV
	E	Accident sequence involving loss of inventory makeup in which the reactor pressure remains high and DC power is unavailable.	
Class II	A	Accident sequences involving a loss of containment heat removal with the RPV initially intact; core damage induced post containment failure	TW
	L	Accident sequences involving a loss of containment heat removal with the RPV breached but no initial core damage; core damage after containment failure.	AW
	T	Accident sequences involving a loss of containment heat removal with the RPV initially intact; core damage induced post high containment pressure	N/A
	V	Class IIA or IL except that the vent operates as designed; loss of makeup occurs at some time following vent initiation. Suppression pool saturated but intact.	TW

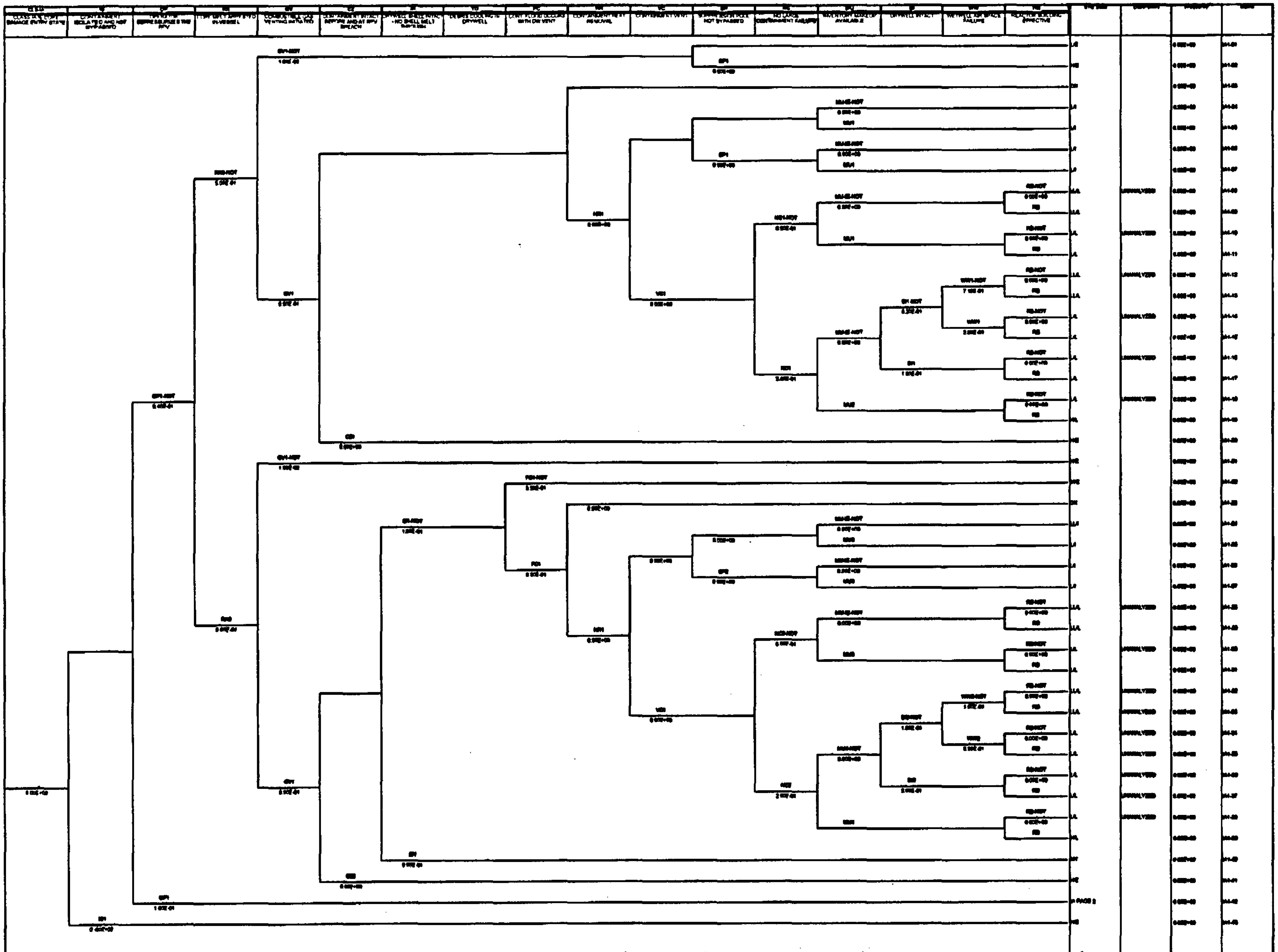
Table 3-6
Summary of the Core Damage
Accident Sequence Subclasses

Accident Class Designator	Subclass	Definition	WASH-1400 Designator Example
Class III (LOCA)	A	Accident sequences leading to core damage conditions initiated by vessel rupture where the containment integrity is not breached in the initial time phase of the accident.	R
	B	Accident sequences initiated or resulting in small or medium LOCAs for which the reactor cannot be depressurized prior to core damage occurring.	S_1QUX
	C	Accident sequences initiated or resulting in medium or large LOCAs for which the reactor is at low pressure and no effective injection is available.	AV
	D	Accident sequences which are initiated by a LOCA or RPV failure and for which the vapor suppression system is inadequate, challenging the containment integrity with subsequent failure of makeup systems.	AD
Class IV (ATWS)	A	Accident sequences involving failure of adequate shutdown reactivity with the RPV initially intact; core damage induced post containment failure.	$T_TC_MC_2$
	L	Accident sequences involving a failure of adequate shutdown reactivity with the RPV initially breached (e.g., LOCA or SORV); core damage induced post containment failure.	N/A
	T	Accident sequences involving a failure of adequate shutdown reactivity with the RPV initially intact; core damage induced post high containment pressure.	N/A
	V	Class IV A or L except that the vent operates as designed; loss of makeup occurs at some time following vent initiation. Suppression pool saturated but intact.	N/A
Class V	--	Unisolated LOCA outside containment	N/A

The CET calculation for each cutset uses Boolean logic and fault tree models to process the incoming Level 1 cutsets to ensure that the resulting Radionuclide release frequencies properly reflect the impact on release magnitude and timing of the containment and containment mitigation systems. A typical CET (for Accident Class 1A) is provided in Figure 3-1.

Figure 3-1

Typical Quad Cities Level 2
Containment Event Tree
(1 page)



CLASS IA/IE CET PAGE 1	C:\CAFTA-W\QC\2002A\LEV2\CETS\QC1A1.ETA	6/23/ 3	Page 1

In summary, the Level 1 end states do not translate directly into release categories. Each Level 1 accident sequence (all of the cutsets) is transferred into the appropriate CET. The CET is then used to determine the resulting frequency for each radionuclide release end state from each incoming cutset. This is typical of a full Level 2 for a binned fault tree model. This approach does not involve a matrix that relates Level 1 sequences directly to Radionuclide end states.

Although not created as part of the normal calculation process, the results of the analysis can be binned to show the contribution to each release category by Level 1 end state. Table 3-7 shows the requested results for the base case 02B model.

Table 3-7
Matrix of Level 1 Results with Various Release Categories
Base Case (02B Model)

Level 1 Accident Class	Level 2 Release Category / Level 3 Consequence Category										
	H/E (L2-1)	H/I (L2-2)	H/L [1] (L2-3)	M/E (L2-4)	M/I (L2-5)	M/L [2] (L2-6)	L/E or LL/E (L2-7)	L/I, LL/I, L/L, or LL/L (L2-8)	Class V (L2-9)	Intact (L2-10)	Total
1A/1E	1.2E-07	N/A	5.4E-09	5.9E-08	3.4E-08	N/A	9.6E-09	3.1E-07	N/A	3.3E-07	8.7E-07
1BE	6.3E-10	N/A	0.0E+00	0.0E+00	6.2E-09	0.0E+00	4.0E-11	1.6E-10	N/A	1.5E-08	2.2E-08
1BL	N/A	1.7E-08	0.0E+00	N/A	1.6E-07	0.0E+00	N/A	2.3E-09	N/A	1.3E-07	3.1E-07
1C	0.0E+00	N/A	0.0E+00	0.0E+00	0.0E+00	0.0E+00	6.8E-12	0.0E+00	N/A	4.0E-09	4.0E-09
1D	0.0E+00	N/A	0.0E+00	1.8E-11	1.9E-10	N/A	0.0E+00	2.9E-11	N/A	9.7E-10	1.2E-09
2	2.4E-10	1.8E-08	N/A	3.3E-08	5.9E-07	N/A	N/A	N/A	N/A	0.0E+00	6.5E-07
3B	5.1E-10	0.0E+00	2.7E-11	N/A	1.2E-09	7.0E-11	3.9E-11	1.9E-09	N/A	9.7E-09	1.3E-08
3C	1.1E-07	N/A	0.0E+00	N/A	0.0E+00	0.0E+00	N/A	0.0E+00	N/A	0.0E+00	1.1E-07
3D	1.2E-08	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.0E+00	1.2E-08
4A	6.8E-09	N/A	N/A	1.6E-07	N/A	N/A	N/A	N/A	N/A	0.0E+00	1.7E-07
5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.8E-08	0.0E+00	1.8E-08
Total:	2.5E-07	3.6E-08	5.5E-09 [1]	2.5E-07	8.0E-07	7.0E-11 [2]	9.7E-09	3.2E-07	1.8E-08	5.0E-07	2.2E-06

[1] Included with the H/I Consequence Category (L2-2) for evaluation purposes.
[2] Included with the M/I Consequence Category (L2-5) for evaluation purposes.

RAI 4

Please provide the following information concerning the MELCOR Accident Consequences Code System (MACCS) analyses:

a. The MACCS analysis assumes all releases that occur at ground level and has a thermal content the same as ambient. These assumptions could be non-conservative when estimating offsite consequences. Please provide an assessment of the sensitivity of offsite consequences (doses to the population within 50 miles) to these assumptions.

b. The discussion of meteorology indicates that there are data voids in the 2000 data set used. Interpolation was used between hours if only a brief period of data was missing, and hourly observations from the airport were used to fill larger data voids. Provide a characterization of the magnitude and extent of the data voids and the rationale for using the airport data rather than interpolation. Confirm that the 2000 data set is representative of the QCNPS site and justify its use.

c. Clarify the time periods used for am and pm for the atmospheric mixing heights, (e.g., midnight to noon and noon to midnight, versus sunrise to sunset.)

Response 4(a):

"The MACCS analysis assumes all releases that occur at ground level and has a thermal content the same as ambient. These assumptions could be non-conservative when estimating offsite consequences. Please provide an assessment of the sensitivity of offsite consequences (doses to the population within 50 miles) to these assumptions."

MACCS2 was re-run for all 8 sequences assuming that all plumes originated from the top of the reactor building, at an elevation of 179 feet above grade, rather than ground level (top of reactor building at 736 feet, grade at 557 feet above sea level). Table 4-1 shows the increases that were obtained for each sequence. As can be seen, the calculated dose increase from the elevated release case compared to the ground level release case typically leads to an increase in the dose of up to about 12%, but in a few cases a smaller increase occurred, and in one case a slight reduction resulted (for the containment intact case). The cost associated with each consequence category typically went up by about 10-15% except for the intact case where a reduction in cost occurred. The overall impact using the same assumptions that were utilized in the ER is a $6,242 increase (+5.6%) in the calculated maximum averted cost risk. It is judged that this would not change the results of the SAMA analysis.

Table 4-1
Ratio of Dose Results
(Elevated to Ground-Level Releases)

Consequence Category	MAAP Run	Dose	Cost
L2-1	QC0053	1.05	1.13
L2-2	QC0082	1.01	1.10
L2-4	QC0085	1.07	1.11
L2-5	QC0061	1.10	1.15
L2-7	QC0057	1.10	1.10
L2-8	QC0058	1.12	1.14
L2-9	QC0070	0.97	1.07
L2-10	QC0074	1.12	0.56

Response 4(b):

"The discussion of meteorology indicates that there are data voids in the 2000 data set used. Interpolation was used between hours if only a brief period of data was missing, and hourly observations from the airport were used to fill larger data voids. Provide a characterization of the magnitude and extent of the data voids and the rationale for using the airport data rather than interpolation. Confirm that the 2000 data set is representative of the QCNPS site and justify its use."

The year 2000 meteorological data sets for QCNPS and DNPS were selected due to the fact that they had the least number of data voids (compared to 1998, 1999 and 2001).

For QCNPS, a total of 157 hours had at least one of the key parameters missing during the year 2000. These 157 hours constitute less than 2% of the total number of hours of data collected during the year 2000. A 51-hour period of consecutive missing wind direction data existed at QCNPS during the year 2000. A 56-hour period of consecutive missing stability (delta t) data also existed. No other periods greater than seven consecutive hours existed. When possible, interpolation or data from other tower measurements was used to fill these smaller data gaps. For the two longer periods, data from the Quad Cities Airport was used.

Due to the rather small extent of the data voids, it is believed that the data set is representative of the QCNPS site.

Response 4(c):

"Clarify the time periods used for am and pm for the atmospheric mixing heights, (e.g., midnight to noon and noon to midnight, versus sunrise to sunset.)"

The original source (George C. Holworth, "Mixing Heights, Wind Speeds, and Potential for Urban Air Pollution throughout the Contiguous United States," USEPA Office of Air Programs, January 1972) did not use the words "am" or "pm", but actually referred to "morning" and "afternoon" mixing heights. This source defined morning as being the four-hour period from 0200 to 0600 Local Standard Time and afternoon as being the four-hour period from 1200 to 1600 Local Standard Time.

The Code Manual for MACCS2: Volume 1 (from Appendix B, page B-2) states the following:

> "The first of these two values corresponds to the morning mixing height and the second to the afternoon height. In the current implementation, the larger of these two values and the value of the boundary weather mixing height is used by the code."
>
> "In its present form, that atmospheric model implemented in MACCS2 does not allow a change in the mixing layer to occur during transport of the plume. Mixing layer height is assumed to be constant and therefore only a single value is used by the code."

Since the Quad Cities MACCS2 analyses considered plumes that have durations in excess of 12 hours (some as long as 24 hours), these conditions mean that, for all intents and purposes, only the afternoon mixing height is used since it is always larger than the morning mixing height. Note that the boundary weather mixing height, wind speed and stability category are only used when there is no met data file. These fixed values are ignored by the code when an hourly met data file is supplied by the user, as was the case in the MACCS2 runs for Quad Cities.

RAI 5

According to Table F-1 of the Environmental Report (ER), Exelon evaluated 280 SAMA candidates. Of these 280 candidates, 30 were obtained from QCNPS-specific documents. It is not clear that the set of SAMAs evaluated in the ER addresses the major risk contributors for QCNPS. In this regard, please provide the following:

a. *a description of how the dominant risk contributors at QCNPS, including dominant sequences and cut sets from the current Probabilistic Risk Assessment (PRA) and equipment failures and operator actions identified through importance analyses (e.g., Fussell-Vesely, Risk Reduction Worth, etc.) were used to identify potential plant-specific SAMAs for QCNPS.*

b. *the number of sequences and cut sets reviewed/evaluated and what percentage of the total CDF they represent.*

c. *a listing of equipment failures and human actions that have the greatest potential for reducing risk at QCNPS based on importance analysis and cut set screening.*

d. *for each dominant contributor identified in the current PRA (Revision 02B), a cross-reference to the SAMAs evaluated in the ER which addresses that contributor. If a SAMA was not evaluated for a dominant risk contributor, justify why SAMAs to further reduce these contributors would not be cost beneficial.*

e. *a general description of the group of 81 insights mentioned in the original IPE and a discussion of how and whether insights not implemented were factored into the SAMA evaluation.*

Response 5(a):

"[Provide] a description of how the dominant risk contributors at QCNPS, including dominant sequences and cut sets from the current Probabilistic Risk Assessment (PRA) and equipment failures and operator actions identified through importance analyses (e.g., Fussell-Vesely, Risk Reduction Worth, etc.) were used to identify potential plant-specific SAMAs for QCNPS"

A review of the CDF-based Risk Reduction Worth (RRW) rankings for the current model was performed. The rankings of these equipment failures, operator actions, and initiating events were checked to determine if any items could be beneficial that were not addressed by the existing SAMA list. The examination of the dominant RRW basic events encompassed the dominant sequences and cut sets from the current PRA model. RAI response 5(d) provides a more detailed discussion of this importance ranking review.

Response 5(b):

"[Provide] the number of sequences and cut sets reviewed/evaluated and what percentage of the total CDF they represent."

The CDF-based RRW listing was reviewed down to and including the 1.02 level, which indicates the events below this point would influence the CDF by less than 2.0%. This corresponds to about a $2,000 averted cost-risk based on CDF reduction assuming 100% reliability of the associated event. An evaluation of the top LERF-based contributors to RRW was also performed. It was determined that a similar averted cost of about $2,000 would be obtained by examining the LERF-based RRW factors down to 1.10. RAI response 5(d) provides a more detailed discussion of the importance ranking review and the results.

Response 5(c):

"[Provide] a listing of equipment failures and human actions that have the greatest potential for reducing risk at QCNPS based on importance analysis and cut set screening."

RAI response 5(d) provides a listing of equipment failures, human actions, and initiating events that have the greatest potential for reducing risk at QCNPS based on importance analysis and cut set screening.

Response 5(d):

"[Provide] for each dominant contributor identified in the current PRA (Revision 02B), a cross-reference to the SAMAs evaluated in the ER which addresses that contributor. If a SAMA was not evaluated for a dominant risk contributor, justify why SAMAs to further reduce these contributors would not be cost beneficial."

Table 5-1 (for CDF) and Table 5-2 (for LERF) provide a correlation between the events identified in the QCNPS PSA model (Revision 02B) that are considered to have the greatest potential for reducing risk and their relationship to the SAMAs evaluated in the Environmental Report.

The events included in Table 5-1 are based on the core damage frequency RRW factors down to and including RRW values of 1.02. The events included in Table 5-2 are based on the large early release frequency RRW factors down to an RRW value of 1.10. Both of these RRW factors correspond to potential averted cost risk of about $2,000. The events below this point are judged to be highly unlikely contributors to the identification of cost-beneficial enhancements.

Table 5-1
Correlation of CDF Importance Listing to Evaluated SAMAs

Event Name	Probability	RRW	Basic Event Description	Disposition
%TDC	1.50E-06	1.54	LOSS OF 125VDC BUSES 1 AND 2 INITIATING EVENT	This event represents the unlikely initiating event of a complete loss of both 125V DC buses. Many SAMAs were included that address potential enhancements for DC reliability and/or alternate means of providing DC power. Phase I SAMAs 93, 94, 97, 98, 99, 100, 114, 125, 126, 127, 128, 129, and 131 are all related to improved DC performance. Phase I SAMAs 94 and 131 were retained for further examination as Phase II SAMAs 3 and 6, respectively. No additional SAMAs were suggested for this broad topic.
1DCRX-BUS1RECF--	7.10E-01	1.54	FAILURE TO RECOVER UNIT 1 BATTERY BUS #1	This event involves failure to recover one of the 125V DC buses given loss of both. See disposition above for %TDC (Loss of 125V DC Buses 1 and 2 Initiating Event).
2DCRX-BUS2RECF--	7.10E-01	1.54	FAILURE TO RECOVER UNIT 2 BATTERY BUS #2	This event involves failure to recover one of the 125V DC buses given loss of both. See disposition above for %TDC (Loss of 125V DC Buses 1 and 2 Initiating Event).
1RHOPREPAIRTRH--	2.60E-01	1.27	FAILURE TO RECOVER/ REPAIR SPC BEFORE VENT (TRANSIENT/IORV)	This event represents the failure to recover or repair suppression pool cooling prior to venting. Potential improvements to the reliability of the RHR heat exchangers were examined in Phase I SAMAs 20 and 22. Alternate means of providing containment heat removal were also examined in Phase I SAMAs 35, 36, 37, 38, 39, 40, 53, 55, 66, 74, 75, 76, 83, 213, 214, and 265. Improvements in the response to containment heat removal events were examined in Phase I SAMAs 277, 278, 279, and 280. Phase I SAMAs 36, 265, and 279 were retained as Phase II SAMAs 2, 13, and 14, respectively. No additional SAMAs were suggested for this broad topic.

Table 5-1
Correlation of CDF Importance Listing to Evaluated SAMAs

Event Name	Probability	RRW	Basic Event Description	Disposition
%DLOOP	1.20E-02	1.20	DUAL UNIT LOSS OF OFFSITE POWER	This event is a dual unit loss of offsite power event. Improvements related to enhanced AC or DC reliability or availability were considered in Phase I SAMAs 91 through 131. Many other SAMAs were also considered that would provide mitigation benefits in loss of offsite power scenarios including Phase II SAMAs 1, 2, 3, 4, 5, 6, 8, 10, and 13. No additional SAMAs were suggested for this broad topic.
%TSW	5.27E-03	1.16	LOSS OF SERVICE WATER INITIATING EVENT	This event is the loss of service water initiating event. Potential improvements and enhancements to the service water system were examined in Phase I SAMAs 10, 20, 21, and 23. No additional SAMAs were suggested, and no related SAMAs were retained for Phase II. It is noted that in Phase I SAMA 23, the cost of installing an additional service water pump had been estimated at approximately $5.9 million which is greater than the maximum averted cost risk (even if large uncertainties and external events are considered).
BACRXDLOOP4HRH--	2.20E-01	1.16	FAILURE TO RECOVER DLOOP WITHIN 4 HRS	This event signifies the time available to recover power prior to battery depletion. Potential improvement to battery life by using fuel cells instead of lead-acid batteries was examined in Phase I SAMA 94 which was retained as Phase II SAMA 3. The cost benefit analysis indicated a potential averted cost-risk of $4,406. The benefit would not be much greater from including fire external events since the Quad Fire PRA results are dominated by loss of decay heat removal scenarios, for which extended battery life would not come into play. The relatively low benefit also excluded other potential low cost alternatives to extending battery life such as portable chargers.

Table 5-1
Correlation of CDF Importance Listing to Evaluated SAMAs

Event Name	Probability	RRW	Basic Event Description	Disposition
BSSOPSSRMCLNGH--	1.10E-01	1.10	OP ACT: ALIGN FP TO SSMP ROOM COOLERS (QCOP 2900-02)	This event represents the human error probability of providing the alternate SSMP room cooling via manual alignment to the Fire Protection System. Phase I SAMA 32 included an examination of providing alternate SSMP room cooling. This SAMA was retained as Phase II SAMA 1 that resulted in a potential averted cost risk of $11,303. It was estimated that the cost of implementing a backup or automating the existing backup system would be substantially higher than the potential averted cost. Also see revised Phase II SAMA disposition in Table 7-3.
1RPCDRPS-MECHFCC	2.10E-06	1.09	MECHANICAL SCRAM FAILURE	This event represents the Mechanical Scram failure probability based on the NUREG/CR-5500 INEEL evaluation of a representative BWR RPS system. Potential improvements to minimize the risks associated with ATWS scenarios were explored in Phase I SAMAs 227-243. Phase I SAMAs 242 and 243 were retained as Phase II SAMAs 11 and 12, respectively. No additional SAMAs were suggested for this broad topic.
BDGCBEDG/SBOSKCC	4.83E-05	1.06	CCF OF ALL EDG/SBO OUTPUT CIRCUIT BREAKERS TO CLOSE	This event represents the unlikely event of all of the diesel generator output breakers failing to close leading to an SBO scenario. See disposition above for %DLOOP (Dual unit Loss of Offsite Power).
%TT	8.81E-01	1.06	TURBINE TRIP WITH BYPASS	This event represents the turbine trip initiating event frequency. Industry efforts over the last fifteen years have led to a significant reduction in the number of reactor scrams and turbine trips. Many of the SAMAs explored potential benefits for mitigation from these events. No additional SAMAs were suggested for this broad topic.

Table 5-1
Correlation of CDF Importance Listing to Evaluated SAMAs

Event Name	Probability	RRW	Basic Event Description	Disposition
1CNPVDWRUPT--R--	6.00E-02	1.06	LARGE DW CONTAINMENT FAILURE CAUSES LOSS OF INJECTION	This event represents the scenario where an unmitigated containment pressurization results in a large drywell region containment failure leading to a loss of all injection systems. This scenario can be avoided by providing improved decay heat removal methods. See disposition above for 1RHOPREPAIRTRH-- (Failure to recover/repair SPC before vent).
%TBCCW	4.92E-03	1.05	LOSS OF TBCCW INITIATING EVENT	This event represents the loss of TBCCW initiating event frequency. Phase I SAMA 20 explored enhanced procedural guidance for use of cross-tied component cooling or service water pumps. The current procedural guidance was deemed adequate for service water, DGCW, and RHRSW, but inter-unit cross-tie capability does not exist for RBCCW or TBCCW. A separate analysis examines the potential cost-benefit of implementing an inter-unit TBCCW cross-tie capabilities (see Response 7(c)).
%S1	3.80E-04	1.05	MEDIUM LOCA (WATER) INITIATOR	This event represents the medium LOCA water line break initiating event frequency. The dominant cutsets associated with this initiator include common cause failures of ECCS strainers or pre-initiator HEPs for miscalibration of pressure switches. Both of these types of events are extremely unlikely, but are included in the model for completeness. No additional SAMAs were suggested.

Table 5-1
Correlation of CDF Importance Listing to Evaluated SAMAs

Event Name	Probability	RRW	Basic Event Description	Disposition
1MSOPMSIVINLKH--	9.10E-01	1.05	OP ACT: BYPASS LOW LEVEL MSIV INTERLOCK GIVEN FAILURE TO SCRAM	This event represents the human error probability of bypassing the MSIV isolation as directed in the EOPs. This action requires the use of jumpers with a limited time available, and as such carries a relatively high HEP value. A dedicated switch for bypassing the low level interlock would be desirable. This issue was specifically examined in Phase I SAMA 237 that was listed as retained, but did not specifically involve a Phase II SAMA analysis. The potential benefit of implementing a dedicated low level interlock switch is also examined (see Response 7(c)).
1RSMV1001-5ABDCC	2.00E-04	1.04	RHR HX RWRSW OUTLET VALVES MOV 1-1001-5A AND 5B AND FAIL TO OPEN	This event represents the unlikely failure of the RHR heat exchanger RHRSW outlet valves leading to a loss of suppression pool cooling capabilities. See disposition above for 1RHOPREPAIRTRH-- (Failure to recover/repair SPC before vent).
BDGDGRUN----XCC	2.94E-05	1.04	CCFTR OF ALL EDGs & BOTH SBOs	This event represents the unlikely failure of all of the diesel generators failing to run leading to an SBO scenario. See disposition above for %DLOOP (Dual unit Loss of Offsite Power).
BSS--MAINT---M--	2.26E-02	1.04	SSMP SYSTEM UNAVAILABLE DUE TO MAINTENANCE	This events represents the SSMP Maintenance unavailability probability. SSMP is a risk significant system with performance monitored as part of the Maintenance Rule activities. Potential improvements to SSMP reliability/operation were examined in Phase I SAMAs 32, 217, and 218. Alternate means of providing injection to the RPV were examined in Phase I SAMAs 184, 185, 186, 192, 208, 210, 211, 212, and 215. Phase I SAMA 32 was retained as Phase II SAMA 1. No other SAMAs were suggested.

Table 5-1
Correlation of CDF Importance Listing to Evaluated SAMAs

Event Name	Probability	RRW	Basic Event Description	Disposition
%TIA	1.22E-02	1.03	LOSS OF INSTRUMENT AIR INITIATOR	This event represents the loss of instrument air initiating event frequency. Potential improvements to air/gas systems were examined in Phase I SAMAs 222-226. No SAMAs were initially retained for Phase II, and no additional SAMAs were suggested. However, a more thorough examination of the Quad Cities Fire PRA leads to a potential benefit being identified by providing an alternate air source to the containment vent valves. The potential benefit of implementing such a change is also explored (see Phase II SAMA 17).
%MS	3.07E+00	1.03	MANUAL SHUTDOWN INITIATING EVENT	This event represents the manual shutdown initiating event frequency. Industry efforts over the last fifteen years have led to a significant reduction in the number of manual shutdowns and scrams from all causes. Many of the SAMAs explored potential benefits for mitigation from these events. No additional SAMAs were suggested for this broad topic.
1CNFLMLLOCA--PCC	1.00E-04	1.03	COMMON CAUSE PLUGGING OF ECCS SUCTION STRAINERS	This event represents the unlikely occurrence of a common cause failure of the ECCS suction strainers. The Quad Cities strainers have recently been upgraded and re-sized such that the potential for common cause plugging has been reduced. No additional SAMAs were suggested.
%TC	7.90E-02	1.03	LOSS OF CONDENSER VACUUM	This event represents the loss of condenser vacuum initiating event frequency. Industry efforts over the last fifteen years have led to a significant reduction in the number of plant scrams from all causes. Many of the SAMAs explored potential benefits for mitigation from these events. No additional SAMAs were suggested for this broad topic.
1IARXRCOVERIAH--	1.48E-01	1.03	OP ACT: RESTORE IAS AFTER IE OR RANDOM FAILURE FOR VENTING	This event represents the restoration of instrument air given instrument air system loss in time for containment venting. See disposition above for %TIA (Loss of Instrument Air Initiator).

Table 5-1
Correlation of CDF Importance Listing to Evaluated SAMAs

Event Name	Probability	RRW	Basic Event Description	Disposition
%LOOP	1.35E-02	1.02	LOSS OF OFFSITE POWER INITIATING EVENT	This event represents the single unit loss of offsite power initiating event frequency. See disposition above for %DLOOP (Dual unit Loss of Offsite Power).
BDGDGSTART---ACC	1.88E-05	1.02	CCFTS OF ALL EDGs & BOTH SBOs	This event represents the unlikely failure of all of the diesel generators failing to start leading to an SBO scenario. See disposition above for %DLOOP (Dual unit Loss of Offsite Power).
1--RX-SPC-SSCH--	1.00E-06	1.02	OP FAILS TO INITIATE SPC, CONTROL CCST, AND ALIGN FP TO SSMP	This event represents the unlikely scenario of combined operator action failures for three separate actions that otherwise are evaluated independently. This event is included for completeness as part of the human reliability dependency analysis. Phase I SAMAs 266 and 271 examine potential improvements in operator performance. No additional SAMAs were suggested for this topic.
1--RX-HPI-ADSH--	1.10E-04	1.02	OPERATOR FAILS TO INITIATE HPCI/RCIC/SSMP AND ADS	This event represents the unlikely scenario of combined operator action failures for separate actions that otherwise are evaluated independently. This event is included for completeness as part of the human reliability dependency analysis. Phase I SAMAs 266 and 271 examine potential improvements in operator performance. No additional SAMAs were suggested for this topic.
1RHMV16AB----KCC	1.10E-04	1.02	RHR HX BYPASS VALVES 16A AND 16B FAIL TO CLOSE DUE TO COMMON CAUSE	This event represents the unlikely failure of the RHR heat exchanger bypass valves leading to a loss of suppression pool cooling capabilities. See disposition above for 1RHOPREPAIRTRH-- (Failure to recover/repair SPC before vent).

Table 5-1
Correlation of CDF Importance Listing to Evaluated SAMAs

Event Name	Probability	RRW	Basic Event Description	Disposition
1CAHU263-52ABHCC	8.00E-05	1.02	PREINIT: CAS PRESSURE SWITCHES 52A AND 52B MISCALIBRATED	This event represents the unlikely scenario of miscalibration of pressure switches leading to unavailability of ECCS injection. This is included for completeness in the model since it has the potential of leading to core damage following a medium or large LOCA initiating event. No additional SAMAs are suggested for this topic.
%A	1.80E-04	1.02	LARGE LOCA INITIATOR	This event represents the Large LOCA initiating event frequency. Mitigation from such an event would be improved by the existence of more reliable or diverse low pressure injection systems and water sources. Such potential improvements were examined in Phase I SAMAs 60, 170,182, 184, 187, 188, 195, 201, 204, 212, 215, and 250. None of these SAMAs were maintained for Phase II, and no additional SAMAs were suggested.
BDCBY125VDC--FCC	1.24E-06	1.02	COMMON CAUSE FAILURE OF UNIT 1 AND UNIT 2 125VDC BATTERIES	This event represents the unlikely scenario with common cause failure of both 125V DC batteries. See disposition above for %TDC (Loss of 125V DC Buses 1 and 2 Initiating Event).
%TF	1.90E-02	1.02	LOSS OF FEEDWATER	This event represents the loss of feedwater initiating event frequency. Industry efforts over the last fifteen years have led to a significant reduction in the number of plant scrams from all causes. Many of the SAMAs explored potential benefits for mitigation from these events. No additional SAMAs were suggested for this broad topic.
1RHMV18AB—DCC	1.01E-04	1.02	MIN-FLOW MOVS 18A AND 18B FAIL TO OPEN DUE TO COMMON CAUSE	This event represents the unlikely failure of the RHR min-flow valves leading to a loss of suppression pool cooling capabilities. See disposition above for 1RHOPREPAIRTRH– (Failure to recover/repair SPC before vent).

Table 5-1
Correlation of CDF Importance Listing to Evaluated SAMAs

Event Name	Probability	RRW	Basic Event Description	Disposition
1LIOP-LPFILL-H--	1.80E-02	1.02	OP ACT: PRVNT OVRFL OF RPV DUE TO UNCNTRLD INJCTION W/ DPRS & USE O	This event represents the human error probability to prevent uncontrolled injection and overfill in ATWS scenarios. Many potential improvements to minimize the risks associated with ATWS scenarios were explored in Phase I SAMAs 227-243. Phase I SAMAs 242 and 243 were retained as Phase II SAMAs 11 and 12, respectively. No additional SAMAs were suggested for this broad topic.
1RSHU-MISCAL1HCC	8.00E-05	1.02	PREINIT: RHRSW PUMPs A, B, C, and D RUNNING LOGIC COMMON MISCAL.	This event represents the unlikely pre-initiator failure of the RHRSW pumps leading to a loss of suppression pool cooling capabilities. See disposition above for 1RHOPREPAIRTRH-- (Failure to recover/repair SPC before vent).
1SLEV-1106A/BDCC	1.40E-02	1.02	SBLC EXPLOSIVE VALVES FAILURE TO OPEN DUE TO CCF	This event represents the common cause failure of the SBLC explosive valves. Phase 1 SAMA 242 specifically examined the potential benefit from diversifying the SBLC explosive valve operation. This SAMA was retained as Phase II SAMA 11. The averted cost-risk was determined to be $2,390, and it was judged that any hardware changes to the SBLC explosive valves would exceed this potential averted cost.

Table 5-2
Correlation of LERF Importance Listing to Evaluated SAMAs

Event Name	Probability	RRW	Basic Event Description	Disposition
1RXSY-RXFAIL-FSU	1.00E+00	7.89	FAILURE OF RX (CLASSES ID, IE (OP=F), II, IIIA, IIIC, IIID, IV)	This event is a Level 2 sequence marker flag identifying those sequences where the RX node has failed (i.e., where core damage was not terminated prior to the time of vessel failure). The capability to enhance or provide additional injection systems was examined in Phase I SAMAs 19, 32, 172, 182, 184-188, 191, 192, 194-196, 200, 201, 203-205, 207-212, 215, 217, and 219-221. Phase I SAMAs 32, 219, 220, and 221 were retained as Phase II SAMAs 1, 8, 9, and 10, respectively. No additional SAMAs were suggested.
1GVPH-INERT--X--	9.90E-01	6.09	CONTAINMENT INERTED; VENTING REQUIRED	This event is effectively a Level 2 sequence marker flag that represents the normal operating condition with the containment inerted. No additional SAMAs were suggested.
1SIPHCONTFAILF--	1.00E+00	1.69	DW SHELL MELT-THROUGH FAILURE DUE TO CONT. FAILURE	This event represents the evaluated likelihood from the Level 2 analysis that a dry containment floor will lead to shell liner failure (i.e., containment failure) after vessel failure for accident classes II, IIID, and IV. The importance of this phenomena would be reduced by the presence of more reliable or diverse injection systems, more reliable or diverse drywell spray systems, and other alternate means to avoid this situation. SAMAs related to improved injection system performance are discussed in the disposition for 1RXSY-RXFAIL-FSU above. Items related to improved drywell spray performance were considered in Phase I SAMAs 36, 37, 53, 55, and 83. Phase I SAMA 36 was retained as Phase II SAMA 2. Alternate strategies for reducing the potential for drywell shell melt-through were also examined in Phase I SAMAs 44, 45, 48, 49, 51, 57, 58, and 87. None of these, however, were retained for Phase II, and no additional SAMAs were suggested.

Table 5-2
Correlation of LERF Importance Listing to Evaluated SAMAs

Event Name	Probability	RRW	Basic Event Description	Disposition
1OPPH-PRESBK-F--	8.00E-01	1.68	PRESSURE TRANSIENT DOES NOT FAIL MECHANICAL SYSTEMS	This event represents a Level 2 phenomena event that would lead to a depressurized state. Potential improvements to the current depressurization capabilities and methods were examined in Phase I SAMAs 197, 198, 224, 245, 246, 253, 256, 257, and 263. None of these, however, were retained for Phase II, and no additional SAMAs were suggested.
1OPPH-SORV---F--	5.50E-01	1.68	SRVs DO NOT FAIL OPEN DURING CORE MELT PROGRESSION	This event also represents a Level 2 phenomena event that would lead to a depressurized state. See disposition above for 1OPPH-PRESBK-F-- (Pressure transient does not fail mechanical systems).
1OPPH-TEMPBK-F--	7.00E-01	1.68	HIGH PRIM SYS TEMP DOES NOT CAUSE FAIL OF RCS PRESS. BOUND	This event also represents a Level 2 phenomena event that would lead to a depressurized state. See disposition above for 1OPPH-PRESBK-F-- (Pressure transient does not fail mechanical systems).
%TDC	1.50E-06	1.67	LOSS OF 125VDC BUSES 1 AND 2 INITIATING EVENT	This event also appears in the CDF importance listing in Table 5-1. It represents the unlikely initiating event of a complete loss of both 125V DC buses. Many SAMAs were included that address potential enhancements for DC reliability and/or alternate means of providing DC power. Phase I SAMAs 93, 94, 97, 98, 99, 100, 114, 125, 126, 127, 128, 129, and 131 are all related to improved DC performance. Phase I SAMAs 94 and 131 were retained for further examination as Phase II SAMAs 3 and 6, respectively. No additional SAMAs were suggested for this broad topic.
1DCRX-BUS1RECF--	7.10E-01	1.67	FAILURE TO RECOVER UNIT 1 BATTERY BUS #1	This event also appears in the CDF importance listing in Table 5-1. It involves failure to recover one of the 125V DC buses given loss of both. See disposition above for %TDC (Loss of 125V DC Buses 1 and 2 Initiating Event).

Table 5-2
Correlation of LERF Importance Listing to Evaluated SAMAs

Event Name	Probability	RRW	Basic Event Description	Disposition
2DCRX-BUS2RECF--	7.10E-01	1.67	FAILURE TO RECOVER UNIT 2 BATTERY BUS #2	This event also appears in the CDF importance listing in Table 5-1. It involves failure to recover one of the 125V DC buses given loss of both. See disposition above for %TDC (Loss of 125V DC Buses 1 and 2 Initiating Event).
1OPOP-DEPRESSH--	5.20E-01	1.63	OP FAILS TO DEPRESS GIVEN OP FAILED IN LVL1 OR LOSS OF DC	This event represents the conditional failure probability used in the Level 2 analysis for operators to depressurize prior to vessel failure given that depressurization was unsuccessful to avert core damage. Potential improvements to the current depressurization capabilities and methods were examined in Phase I SAMAs 197, 198, 224, 245, 246, 253, 256, 257, and 263. None of these, however, were retained for Phase II, and no additional SAMAs were suggested.
%S1	3.80E-04	1.39	MEDIUM LOCA (WATER) INITIATOR	This event also appears in the CDF importance listing in Table 5-1. It represents the medium LOCA water line break initiating event frequency. The dominant cutsets associated with this initiator include common cause failures of ECCS strainers or pre-initiator HEPs for miscalibration of pressure switches. Both of these types of events are extremely unlikely, but are included in the model for completeness. No additional SAMAs were suggested.
1SIPH-DWHEAD-F--	5.00E-01	1.30	DRYWELL HEAD CLOSURE FAILS DUE TO OVERPRESSURE	This event is a Level 2 phenomena event that represents the probability that a high pressure vessel failure scenario will lead to an early containment failure given that water exists on the drywell floor at the time of vessel failure. The importance of this event would be minimized by reducing the number of high pressure vessel failure scenarios. See disposition above for 1OPOP-DEPRESSH-- (Operator fails to depressurize given failed in Level 1 or loss of DC). No additional SAMAs were suggested.

Table 5-2
Correlation of LERF Importance Listing to Evaluated SAMAs

Event Name	Probability	RRW	Basic Event Description	Disposition
1CNFLMLLOCA--PCC	1.00E-04	1.27	COMMON CAUSE PLUGGING OF ECCS SUCTION STRAINERS	This event also appears in the CDF importance listing in Table 5-1. It represents the unlikely occurrence of a common cause failure of the ECCS suction strainers. The Quad Cities strainers have recently been upgraded and re-sized such that the potential for common cause plugging has been reduced. No additional SAMAs were suggested.
1CAHU263-52ABHCC	8.00E-05	1.21	PREINIT: CAS PRESSURE SWITCHES 52A AND 52B MISCALIBRATED	This event also appears in the CDF importance listing in Table 5-1. It represents the unlikely scenario of miscalibration of pressure switches leading to unavailability of ECCS injection. This is included for completeness in the model since it has the potential of leading to core damage following a medium or large LOCA initiating event. No additional SAMAs are suggested for this topic.
%A	1.80E-04	1.20	LARGE LOCA INITIATOR	This event also appears in the CDF importance listing in Table 5-1. It represents the Large LOCA initiating event frequency. Mitigation from such an event would be improved by the existence of more reliable or diverse low pressure injection systems and water sources. Such potential improvements were examined in Phase I SAMAs 60, 170,182, 184, 187, 188, 195, 201, 204, 212, 215, and 250. None of these SAMAs were maintained for Phase II, and no additional SAMAs were suggested.
1SIPH-SI2-NOTFSU	5.00E-01	1.11	DRYWELL SHELL INTACT (OP=F)	This event represents the complement to the Level 2 phenomena event 1SIPH-DWHEAD-F-- discussed above. As such, no additional SAMAs were suggested.

Response 5(e):

"[Provide] a general description of the group of 81 insights mentioned in the original IPE and a discussion of how and whether insights not implemented were factored into the SAMA evaluation."

One of the important means of identifying plant specific improvements for the Quad Cities SAMA analysis was a review of the plant's IPE. As part of the IPE, an analysis of the cutsets and importance rankings was performed in order to identify plant weaknesses and to suggest changes that would address the weaknesses identified. There were a total of 172 items that were developed from the IPE that were later categorized as IPE or Accident Management insights. These items generally consisted of the following types of improvements:

- Accident Management insights (70)
- Potential procedural enhancements (57)
- Potential hardware modifications (24)
- Mention of good practices (13)
- Recommendations for better data tracking of reliability performance (4)
- Suggestions for training or analysis (2)
- Simple information only (2)

A review of these insights indicates that the disposition is as follows:

- Accident management insights from several sites including Quad Cities were carefully considered by the BWROG in developing the EOPs and SAMGs that have been subsequently implemented at Quad Cities. Authors of the plant-specific QC SAMG's also reviewed and incorporated, as appropriate, the Quad Accident Management Insights from the Quad IPE. No additional action required.
- Of the 57 potential procedural enhancements, 13 were found to have been addressed with subsequent revisions of the procedures. Of the remaining 44 procedural insights, 21 were found to have been addressed in other procedures, 14 were found to provide superfluous information to existing procedures, and 9 were found to be too specific to provide useful information in the symptom-based procedures. No additional action required.
- Of the 24 hardware modifications, 7 were determined to be unnecessary and 2 have been made irrelevant through implementation of the Maintenance Rule. The remaining 15 hardware modifications are safety improvements. However, given the current risk profile and current equipment performance, they have minimal safety benefit and, therefore, are not cost effective. No additional action required.
- The mention of good practices did not require a response. No action required.
- The other 4 recommendations are now considered part of the ordinary Maintenance Rule activities. No additional action required.
- The 2 suggestions for training or analysis are in error.
- The 2 related to providing information are not related to SAMA.

Therefore, no further action for SAMA is appropriate for the 81 IPE insights. The discussion above provides a general description of the IPE insights as requested in the RAI, and since these insights were not factored directly into the SAMA analysis, a detailed table is not deemed necessary.

More recent insights from the updated PRA models were factored directly into the SAMA list. Thirty of the Phase 1 SAMAs include the "Risk Perspectives on Quad Cities" as the reference source (i.e., indicated in Table F-1 of the ER as Reference 83). These thirty items were specifically developed following the completion of the 1999 PRA model update. The completion of the 2002 model update did not lead to any additional insights, as the results did not dramatically change. In any event, a correlation between importance parameters for both CDF and LERF from the 2002 (02B) model and their relationship to the SAMA analysis is provided in Response 5(d). In summary, it was judged that these more recent insights were sufficient and appropriate for supplementing the generic SAMA lists with plant-specific insights. EGC review of the 81 IPE insights in response to this RAI confirms that judgment.

RAI 6

The SAMA analysis did not include an assessment of SAMAs for external events. The QCNPS IPE for External Events (IPEEE) has shown that the CDF due to internal fire initiated events is about 7×10^{-5} per reactor year, which is substantially greater than the internal events CDF on which the SAMA evaluation is based. The risk analyses at other commercial nuclear power plants also indicate that external events could be large contributors to CDF and the overall risk to the public. In this regard, the following additional information is needed:

a. *NUREG-1742 ("Perspectives Gained From the IPEEE Program," Final Report, 4/02), lists the significant fire area CDFs for QCNPS (pages 3-24 and 3-24 of Volume 2). While these fire-related CDF estimates may be conservative, they are still large relative to the QCNPS internal events CDF. For each fire area or dominant fire sequence, please explain what measures were taken to further reduce risk, and explain why these CDFs can not be further reduced in a cost effective manner.*

b. *NUREG-1742 lists seismic outliers and improvements for QCNPS (Tables 2.7 and 2.12 of Volume 2). Please confirm that all of the "Plant improvements" that address the outliers have been implemented. If not, please explain why within the context of this SAMA study.*

c. *In the IPEEE submittal, Exelon estimated that after the resolution of the seismic outliers, the plant high confidence in low probability of failure (HCLPF) would be at least 0.24g which is less than the 0.3g review level earthquake used in the IPEEE. During the EPU evaluation, the staff noted that if the HCLPF capacity was increased to 0.3g, the resulting CDF would be about an order of magnitude reduction in risk from the IPEEE plant condition. Please identify the systems, structures, and components (SSCs) that limit the plant HCLPF. For those SSCs below 0.3g, justify why modifications to increase seismic capacity would not be cost beneficial when evaluated consistent with the regulatory analysis guidelines.*

Response 6(a):

"NUREG-1742 ("Perspectives Gained From the IPEEE Program," Final Report, 4/02), lists the significant fire area CDFs for QCNPS (pages 3-24 and [3-25] of Volume 2). While these fire-related CDF estimates may be conservative, they are still large relative to the QCNPS internal events CDF. For each fire area or dominant fire sequence, please explain what measures were taken to further reduce risk, and explain why these CDFs can not be further reduced in a cost effective manner."

As an IPEEE, the QC fire study was performed primarily to develop risk insights. It was done in the traditional style of fire PRAs, and as such, employs conservatism and involves some level of uncertainty (also see Attachment A that provides more details on the types of conservatisms and uncertainties associated with the use of quantitative results from Fire PRAs). Therefore, it cannot be used directly to provide a realistic cost-benefit analysis as part of the SAMA evaluations.

EGC has, however, used the fire PRA to develop ideas for plant improvement. A large oil fire involving the reactor feedwater pumps was the dominant risk contributor from the IPEEE fire study because of the location of combustibles in proximity to cables and circuits associated with RHR Service Water. In response to this insight, the Station performed a modification to improve the response time of the sprinkler heads in the reactor feedwater pump areas. A sensitivity study with the fire PRA shows that a 25% reduction in fire CDF could be obtained for this modification, alone. Loss of decay heat removal was also identified as important in many fire scenarios. Because of this, another plant enhancement is providing an alternate or redundant air supply for the containment vent valves. Perfect reliability of this redundant air supply had been estimated to reduce the fire CDF by 17%; however, with the sprinkler head modification done, it could be of reduced effectiveness. Nevertheless, the Station is planning to implement a method to provide alternative air supplies in the case of failure of instrument air. Since such a change has not yet been implemented at the site, the idea has been revised to "retained" status in the Phase I SAMA analysis (see Response 7(b), Table 7-2, #225), and is now included as Phase II SAMA 17 (see Response 7(c), Table 7-3).

Fourteen other plant modification ideas were analyzed for potential fire CDF reduction. These ideas were principally developed based on deterministic Appendix R evaluations to enhance Appendix R compliance efforts. The majority of the cases (9) were shown to have less than 1% benefit in fire CDF risk reduction, and therefore the potential improvement was not pursued. These modifications are briefly shown below along with their estimated risk reduction.

• New power source for FIC 1/2-2940-6	0
• Reroute and wrap two cables to separate SSMP from control room	0
• Move SSMP injection point for Unit 1 and Unit 2	0.5%
• Make the battery rooms and DC equipment rooms separate fire areas in both Units	0
• SBO control from control room	0
• Reroute Cables 14196 and 14197 out of TB-III	0
• Reroute control cable (80220) for SBO feed breaker to 14-1	0.5%

- Make the cable tunnels separate fire areas in both Units 0
- Reroute Cable 13968 (for HPCI operation) out of TB-II 0

In the other five cases, a fire CDF reduction estimate was not directly available, but in two of the cases, the potential enhancement was qualitatively determined to have minimal risk benefit, and therefore were not pursued further. This included installation of relays and fuses to improve 125V DC control power availability for 4 kV and 480 V switchgear, respectively. The final three potential enhancements were for rerouting a feed to a 125V DC bus, and providing control room or alternate local control station access for select RHR and RCIC valves, respectively. These were also not pursued because they would require extensive design engineering and analysis work, and the actual benefit could not be readily measured for the fire CDF. Hence, these were also qualitatively evaluated such that the cost exceeds the potential benefit, and were also not pursued further. Therefore, EGC believes that all of the potentially worthwhile improvement ideas have been identified. An additional fire-area-by-fire-area search for improvement ideas will not be productive until Fire PRA technology advances to the point that a direct comparison of the Fire CDF results and the internal events CDF results is possible.

Response 6(b):

"NUREG-1742 lists seismic outliers and improvements for QCNPS (Tables 2.7 and 2.12 of Volume 2). Please confirm that all of the "Plant improvements" that address the outliers have been implemented. If not, please explain why within the context of this SAMA study."

As indicated in NUREG-1742, an extensive number of plant improvements or other actions were planned to resolve the USI A-46 outliers. These improvements pertained primarily to enhancing anchorage/support capacity and reducing or eliminating the potential for adverse interactions. Quad Cities recently informed the NRC that all of the outliers have been resolved. Reference letter from Timothy J. Tulon, Quad Cities Nuclear Power Station, *Completion of Actions Associated With Supplement No. 1 to Generic Letter 87-02: Verification of Seismic Adequacy of Mechanical and Electrical Equipment in Operating Reactors, Unresolved Safety Issue (USI) A-46 (TAC Nos. M69476 and M69477)*, SVP-03-0033, dated February 28, 2003.

Response 6(c):

"In the IPEEE submittal, Exelon estimated that after the resolution of the seismic outliers, the plant high confidence in low probability of failure (HCLPF) would be at least 0.24g which is less than the 0.3g review level earthquake used in the IPEEE. During the EPU evaluation, the staff noted that if the HCLPF capacity was increased to 0.3g, the resulting CDF would be about an order of magnitude reduction in risk from the IPEEE plant condition. Please identify the systems, structures, and components (SSCs) that limit the plant HCLPF. For those SSCs below 0.3g, justify why modifications to increase seismic capacity would not be cost beneficial when evaluated consistent with the regulatory analysis guidelines."

Upon completion of the USI A-46 outliers in February, 2003 as noted in Response 6(b), the current HCLPF for Quad Cities is at least 0.24g. The order of magnitude reduction in CDF noted above from the IPEEE plant condition is a conservative estimate based on a plant with a HCLPF of 0.15g. This estimate was made by the NRC using a bounding method first introduced by EGC in the RAI responses for the Dresden Extended Power Uprate submittal. Using the same conservative approximations with a plant HCLPF of 0.24g would yield approximately a factor of 2 reduction in seismic CDF (i.e., much less than an order of magnitude). However, this should not be compared to a similar reduction in the internal events CDF due to the over-simplification and conservative bias involved in the calculation. Additionally, this factor of 2 reduction would be representative of a plant with all SSCs at exactly 0.24g, whose equipment was all modified to handle 0.3g. In fact, the majority of SSCs at Quad Cities already have HCLPF values of at least 0.3g.

Thirty-four SSCs or categories of cable trays remain with a HCLPF value of 0.24g or higher, but that have not been verified to 0.3g. These remaining SSCs include the following:

- 4 categories of cable trays where improvements have been made to meet 0.24g, but where walkdowns and re-analysis have not been performed to determine how to qualify them to 0.3g. Significant modifications could be required to further increase the seismic capacity.

- 1 is the 2A 125V battery charger, which is good to 0.27g. Additional anchorage improvements would be required to extend the HCLPF to 0.3g. A higher HCLPF value could only be obtained by establishing an additional anchorage point. Minimal benefit is expected from raising the HCLPF value from the current value.

- 3 RHRSW pump room coolers. Any modification would involve some complicated scaffolding design and construction since the coolers are located high above the pumps in the RHRSW pump rooms. Additionally, an analysis of the coolers and design of the modifications would have to occur. Overall analysis and implementation costs would easily exceed the potential averted cost.

- The balance consists of 4 Switchgear and 22 MCCs. They consist of both essential AC and some 250VDC components. They all are currently considered to have 0.24g HCLPF values. The limit is related to the anchorage of equipment to the concrete pad on which the equipment is mounted, and/or bonding of the embedded steel straps that are cast into the concrete to provide stability for the MCCs. Some of these components are near walls, but generally they are in the middle of rooms where bracing would involve installing some kind of "legs" to brace them from the floor, and these potential enhancements could hinder access for maintenance or other activities. Further improvements are not practical.

EPRI has estimated that the SQUG modifications resulted in expenses of $1.4M per plant, but it is estimated that Quad Cities had more SQUG outliers than the average plant. To address the items listed above, it is estimated that this would require a similar effort to the SQUG modifications, or more than $2.0M.

Limited benefit would be obtained by improving the plant HCLPF to 0.3g for all SSCs. Using the methodology from the Dresden EPU RAI responses, the maximum benefit is conservatively estimated at about 2E-6/yr, but practically the actual maximum benefit is quite less. The cost estimate of more than $2.0M precludes this as being cost-beneficial. Cost benefits from individual improvements can also not be easily made at this time without extensive analysis efforts. As such, it is judged that further modifications to increase seismic capacity are not warranted.

RAI 7

The SAMA analysis did not include an assessment of the impact that PRA uncertainties and external event risk considerations would have on the conclusions of the study. Some license renewal applicants have opted to double the estimated benefits (for internal events) to accommodate any contributions for other initiators when sound reasons exist to support such a numerical adjustment, and to incorporate additional margin in the SAMA screening criteria to address uncertainties in other parts of the analysis (e.g., an additional factor of two in comparing costs and benefits of each SAMA). At QCNPS, external events (both fire and seismic) are dominant contributors to the total CDF, and are over a factor of 10 greater than internal event contributions. On that basis, please provide the following information to address these concerns:

a. *an estimate of the uncertainties associated with the calculated core damage frequency (e.g., the mean and median internal events CDF estimates and the 5^{th} and 95^{th} percentile values of the uncertainty distribution),*

b. *an assessment of the impact on the Phase 1 screening if risk reduction estimates are increased to account for uncertainties in the risk assessment and the additional benefits associated with external events (as applicable), and*

c. *an assessment of the impact on the Phase 2 evaluation if risk reduction estimates are increased to account for uncertainties in the risk assessment and the additional benefits associated with external events (as applicable). Please consider the uncertainties due to both the averted cost-risk and the cost of implementation to determine changes in the net value for these SAMAs.*

Response 7(a):

"[Provide] an estimate of the uncertainties associated with the calculated core damage frequency (e.g., the mean and median internal events CDF estimates and the 5^{th} and 95^{th} percentile values of the uncertainty distribution)[.]"

Revision 02B of the Quad Cities PRA model was utilized as the basis for the SAMA analysis performed in support of the environmental report. This version of the model was not populated with uncertainty distributions for the data input parameters. Consequently, development of the median internal events CDF estimates and the 5^{th} and 95^{th} percentile values of the uncertainty distribution are not readily available. (Note that population of the uncertainty distribution parameters is anticipated for a future model revision update) In any event, Table 7-1 provides estimates of internal events Level 1 CDF uncertainty distributions that were obtained for other plants from various sources.

Table 7-1
Representative Core Damage Frequency Uncertainty Distributions

Plant / Model	Point Estimate Mean Value	Para-metric Mean Value	5th Percentile Value	Median Value	95th Percentile Value	95th / P.E. Mean Ratio	Error Factor	Reference
Peach Bottom	3.6E-6 (1)	4.5E-6	3.5E-7	1.9E-6	1.3E-5	3.6	6.1	NUREG/CR-4551, Volume 4, Rev. 1, Part 1 (Table S-1a)
Grand Gulf	2.0E-6 (2)	4.1E-6	1.8E-7	1.1E-6	1.4E-5	7.0	8.8	NUREG/CR-4551, Volume 6, Rev. 1, Part 1 (Table S-2)
LaSalle / RMIEP	3.1E-5	4.4E-5	2.1E-6	1.6E-5	1.4E-4	4.5	8.2	NUREG/CR-4832, Volume 2 (RMIEP), (Table 3.1)
LaSalle / Current	6.64E-6	6.88E-6	2.82E-6	5.20E-6	1.39E-5	2.1	2.2	LS-PSA-014, LaSalle Quantification Notebook, Revision 2, June 2003 (Appendix G)
H.B. Robinson	4.3E-5	4.5E-5	1.5E-5	3.3E-5	1.1E-4	2.6	2.7	Docket No. 50/261 (Response to Request for Additional Information Regarding SAMA Analysis)
V.C. Summer	5.6E-5	5.6E-5	1.9E-5	4.4E-5	1.3E-4	2.3	2.6	Docket No. 50/395 (Response to SAMA Request for Additional Information)

(1) From NUREG/CR-4550, Vol. 4, Rev. 1, Part 1, Page 5-1.
(2) From NUREG/CR-4550, Vol. 6, Rev. 1, Part 1, Page 5-1.

The collective information shown in Table 7-1 indicates that the point estimate to mean ratio could be as little as 2 or as large as 7. The LaSalle/RMIEP distribution parameters are chosen as representative since they represent the second-most broadest distribution. Therefore, a factor of 4.5 increase from the calculated point estimate mean internal events CDF with an error factor of 8 is used as a reasonably conservative estimate to approximate the uncertainty distribution. This correlates to an estimated 95th percentile value of about 1.0E-5/yr for the Quad Cities internal events core damage frequency. Additionally, the assumed error factor of 8 can be used to approximate the median and 5th percentile values as well as is shown below.

Quad Cities Approximated Uncertainty Distribution:

95th Percentile: 4.5 * (Point Estimate Mean) = 1.0E-5/yr

Median: 95th / EF = 1.0E-5/yr / 8 = 1.25E-6/yr

5th Percentile: Median / EF = 1.25E-6/yr / 8 = 1.6E-7/yr

Response 7(b):

"[Provide] an assessment of the impact on the Phase 1 screening if risk reduction estimates are increased to account for uncertainties in the risk assessment and the additional benefits associated with external events (as applicable)[.]"

As indicated in Response 7(a), it is estimated that the 95th percentile value would be approximately a factor of 4.5 higher than the reported point estimate mean CDF value of 2.2E-6. This can be assumed to correspond to an internal events upper bound value of about 1.0E-5/yr.

The Quad Cities Internal Fire risk model was updated in 1999 as part of the revised IPEEE submittal report. The CDF contribution to internal fires was estimated at 6.6E-5/yr for Unit 1 and 7.3E-5/yr for Unit 2. However, plant improvements have occurred since that time as identified in Response 6(a), and the methodology invoked to determine the fire CDF is judged to be highly conservative. Therefore, it is judged that it is not appropriate at this time to directly compare internal events CDF values with the reported Fire CDF values[1].

The seismic portion of the IPEEE program was completed in conjunction with the SQUG program. Quad Cities performed a seismic margins assessment (SMA) following the guidance of NUREG-1407 and EPRI NP-6041. The SMA is a deterministic evaluation that does not calculate risk on a probabilistic basis. No core damage frequency sequences were quantified as part of the seismic risk evaluation. However, an extensive number of plant improvements were identified and these have all been resolved as is noted in Response 6(b).

Consequently, to account for uncertainties in the risk assessment and the potential additional benefits associated with external events, the Phase I screening was re-performed assuming an increase factor of about 5 to the base cost risk for QCNPS to $500K (compared to the base internal events cost-risk of $111,000 used in the ER).

[1] Attachment A provides an assessment of the use of quantitative risk estimates from Fire PRAs, and why it is judged that the calculated CDF values should not be directly compared at this time.

The screening criteria utilized in Table F-1 of the Quad Cities ER includes the following categories:

#1 – Not applicable to the QC design
#2 – Similar item is addressed under other proposed SAMAs
#3 – Already implemented at QC
#4 – No significant safety benefit associated with this SAMA for QC
#5 – Cost of implementation clearly greater than the maximum averted cost risk
#6 – Retained for Phase II analysis
#7 – Not used
#8 – ABWR design issue, not practical

For the revised Phase I screening, SAMA items that previously screened by Criteria #1 or #8 were not re-examined. SAMA items that previously screened by Criteria #2 or #3 were also re-examined to see if an alternative approach to addressing the SAMA could be potentially beneficial, and to look at the potential impact of additional benefits that might be afforded by including external events in the analysis. SAMA items that previously screened by Criteria #4 or #5 were also all re-examined, and the previously retained items (i.e., Criteria #6) were still retained and were subject to re-analysis as described in Response 7(c). The results of the revised Phase I screening for all previous criteria #4, #5, and #6 entries are included in Table 7-2. Criteria #2 or #3 entries are only included in Table 7-2 if the disposition is changed. As can be seen, three additional SAMAs are now retained for Phase II (See Phase I SAMA 20, Phase I SAMA 225, and Phase I SAMA 237).

Table 7-2
Revised Phase I SAMA Disposition (Assuming Maximum Averted Cost Risk of $500K)

Phase I SAMA ID number	SAMA title	Result of potential enhancement	Original / Revised Screening Criteria	Original Disposition	Revised Disposition Including Uncertainty and External Events	Phase II SAMA ID number
19	Use fire protection system pumps as a backup seal injection and high-pressure makeup.	SAMA would reduce the frequency of the RCP seal LOCA and the SBO CDF.	#5 - Cost would be more than risk benefit	Fire protection is a low head system at Quad Cities and cannot currently be used as a HP injection source. Given that recirc pump seal failure is a negligible contributor to Quad Cities risk, no consideration is given to modifying the FP system to provide seal cooling. The ability to provide high pressure injection during an SBO would be beneficial, but the cost of the required modifications would be high. Installation of new high pressure piping, a high head, high flow pump (as it would also have to support the fire system) and a supporting diesel generator or pump motor is similar in scope to SAMA 185. The cost is also considered to be similar ($5 million to $10 million) and is greater than the maximum averted cost-risk for Quad Cities.	The cost is considered to be greater than the upper bound maximum averted cost risk of $500K. No change to the screening criteria category.	N/A
20	Enhance procedural guidance for use of cross-tied component cooling or service water pumps.	SAMA would reduce the frequency of the loss of component cooling water and service water.	#3 - Already implemented at Quad Cities. Revised to: #6 – Retain	At Quad Cities, Service Water is completely cross-tied (between units and divisions). Inter-unit RHRSW and DGCW cross-ties are available via manual valves which are normally closed. The TBCCW pumps discharge to a common header for a given unit, but no inter-unit cross-tie capability currently exists. The same is true or RBCCW. Procedural guidance is adequate.	Investigate potential benefit from improving TBCCW performance based on CDF RRW factor review from Response 5(d).	15
23	8.a. Additional Service Water Pump	SAMA would conceivably reduce common cause dependencies from SW system and thus reduce plant risk through system reliability improvement.	#5 - Cost would be more than risk benefit	The cost of implementing this SAMA has been estimated at approximately $5.9 million and is greater than the maximum averted cost-risk for QC.	The cost is considered to be greater than the upper bound maximum averted cost risk of $500K. No change to the screening criteria category.	N/A

Table 7-2
Revised Phase I SAMA Disposition (Assuming Maximum Averted Cost Risk of $500K)

Phase I SAMA ID number	SAMA title	Result of potential enhancement	Original / Revised Screening Criteria	Original Disposition	Revised Disposition Including Uncertainty and External Events	Phase II SAMA ID number
25	Provide reliable power to control building fans.	SAMA would increase availability of control room ventilation on a loss of power.	#4 - No significant safety benefit	Control Room HVAC has reliable power sources. The B HVAC train is powered by the swing EDG in the event of a loss of offsite power. The A Division is from the unit diesel. In addition, Control Room HVAC is not required for successful accident mitigation.	Considering uncertainty and potential impacts from external events does not introduce any significant changes. No change to the screening criteria category.	N/A
26	Provide a redundant train of ventilation.	SAMA would increase the availability of components dependent on room cooling.	#5 - Cost would be more than risk benefit	It has been determined that room cooling is not required for successful operation of RHR and Core Spray at Quad Cities. RCIC does not require room cooling given that it is not run concurrently with Core Spray, which is assumed to be true in the PSA model. HPCI, Feedwater, the SSMP, RHRSW, and the EDG rooms require room cooling for success over the 24 hour mission time. The cost of installing a redundant, diverse train of HVAC for a Switchgear Room has been estimated at $10 million (Reference 19) and far exceeds the maximum averted cost-risk for Quad Cities ($0.1 million). Providing a redundant train of HVAC for HPCI, Feedwater, the SSMP, and RHRSW is similar in scope and is judged to cost approximately the same; thus, these changes are also screened.	The cost is considered to be greater than the upper bound maximum averted cost risk of $500K. No change to the screening criteria category.	N/A

Table 7-2
Revised Phase I SAMA Disposition (Assuming Maximum Averted Cost Risk of $500K)

Phase I SAMA ID number	SAMA title	Result of potential enhancement	Original / Revised Screening Criteria	Original Disposition	Revised Disposition Including Uncertainty and External Events	Phase II SAMA ID number
29	Create ability to switch fan power supply to DC in an SBO event.	SAMA would allow continued operation in an SBO event. This SAMA was created for reactor core isolation cooling system room at Fitzpatrick Nuclear Power Plant.	#4 - No significant safety benefit	During a postulated SBO, HPCI and RCIC can operate for the duration of the event which is limited by DC battery life. Use of a DC powered fan would increase the drain on the batteries with no impact on the reliability of the HPCI or RCIC systems as long as there is no gland seal failure. For the low probability event of an SBO and gland seal failure the crew is directed to bypass high temperature room trips. This would avoid the trip of HPCI and RCIC. Component failures of these systems could also occur, but this is judged to represent a negligible risk impact. As such there is no measurable safety benefit associated with this SAMA.	Considering uncertainty and potential impacts from external events does not introduce any significant changes. No change to the screening criteria category.	N/A
32	Provide means for alternate SSMP room cooling	The SSMP requires room cooling at extended times. This SAMA would allow SSMP operation late in accidents when normal room cooling has failed.	#6 - Retain	SSMP has alternate room cooling via a manual alignment to FPS. The SAMA would be yet a further enhancement. Evaluate the benefit of providing alternate SSMP room cooling. These options may include: - Controls in the Main Control Room for remote alignment of SW or FPS to SSMP room cooling - Procedures for opening SSMP room doors and using portable fans for SSMP room cooling	Still retained.	1
35	Install an independent method of suppression pool cooling.	SAMA would decrease the probability of loss of containment heat removal. For PWRs, a potential similar enhancement would be to install an independent cooling system for sump water.	#5 - Cost would be more than risk benefit	Installation of a new, independent, suppression pool cooling system is similar in scope to installing a new containment spray system, which has been estimated to cost approximately $5.8 million. This exceeds the maximum averted cost-risk for Quad Cities.	The cost is considered to be greater than the upper bound maximum averted cost risk of $500K. No change to the screening criteria category.	N/A

Table 7-2
Revised Phase I SAMA Disposition (Assuming Maximum Averted Cost Risk of $500K)

Phase I SAMA ID number	SAMA title	Result of potential enhancement	Original / Revised Screening Criteria	Original Disposition	Revised Disposition Including Uncertainty and External Events	Phase II SAMA ID number
36	Develop an enhanced drywell spray system.	SAMA would provide a redundant source of water to the containment to control containment pressure, when used in conjunction with containment heat removal.	#6 - Retain	The Fire Protection system can already provide water to the RHR system at Quad Cities; however, no procedures have been developed to use it as a containment spray source. The containment spray function could be further enhanced at Quad Cities.	Still retained.	2
37	Provide dedicated existing drywell spray system.	SAMA would provide a source of water to the containment to control containment pressure, when used in conjunction with containment heat removal. This would use an existing spray loop instead of developing a new spray system.	#5 - Cost would be more than risk benefit.	Installation of a new, independent, containment spray system has been estimated to cost approximately $5.8 million. This exceeds the maximum averted cost-risk for Quad Cities.	The cost is considered to be greater than the upper bound maximum averted cost risk of $500K. No change to the screening criteria category.	N/A
39	Install a filtered containment vent to remove decay heat.	SAMA would provide an alternate decay heat removal method for non-ATWS events, with the released fission products being scrubbed. Option 1: Gravel Bed Filter Option 2: Multiple Venturi Scrubber	#5 - Cost would be more than risk benefit	Potential to improve both the Level 1 and Level 2 results.	The cost is considered to be greater than the upper bound maximum averted cost risk of $500K. No change to the screening criteria category.	N/A
40	Install a containment vent large enough to remove ATWS decay heat.	Assuming that injection is available, this SAMA would provide alternate decay heat removal in an ATWS event.	#5 - Cost would be more than risk benefit.	Quad Cities does not have a hard pipe vent of sufficient capacity to mitigate ATWS pressurization unless other mitigation steps are successful. The cost of a larger vent is estimated to be in excess of $3 million. This exceeds the maximum averted cost-risk for Quad Cities.	The cost is considered to be greater than the upper bound maximum averted cost risk of $500K. No change to the screening criteria category.	N/A

Table 7-2
Revised Phase I SAMA Disposition (Assuming Maximum Averted Cost Risk of $500K)

Phase I SAMA ID number	SAMA title	Result of potential enhancement	Original / Revised Screening Criteria	Original Disposition	Revised Disposition Including Uncertainty and External Events	Phase II SAMA ID number
44	Create a large concrete crucible with heat removal potential under the basemat to contain molten core debris.	SAMA would ensure that molten core debris escaping from the vessel would be contained within the crucible. The water cooling mechanism would cool the molten core, preventing a melt-through of the basemat.	#5 - Cost would be more than risk benefit	Core retention devices have been investigated in previous studies. IDCOR concluded that "core retention devices are not effective risk reduction devices for degraded core events". Other evaluations have shown the worth value for a core retention device to be on the order of $7000 (averted cost-risk) compared to an estimated implementation cost of over $1 million (per unit).	The cost is considered to be greater than the upper bound maximum averted cost risk of $500K. No change to the screening criteria category.	N/A
45	Create a water-cooled rubble bed on the pedestal.	SAMA would contain molten core debris dropping on to the pedestal and would allow the debris to be cooled.	#5 - Cost would be more than risk benefit	Core retention devices have been investigated in previous studies. IDCOR concluded that "core retention devices are not effective risk reduction devices for degraded core events". Other evaluations have shown the worth value for a core retention device to be on the order of $7000 (averted cost-risk) compared to an estimated implementation cost of over $1 million (per unit).	The cost is considered to be greater than the upper bound maximum averted cost risk of $500K. No change to the screening criteria category.	N/A
46	Provide modification for flooding the drywell head.	SAMA would help mitigate accidents that result in the leakage through the drywell head seal.	#4 - No significant safety benefit	BWR Mark I risk is typically dominated by events that result in early failure of the drywell shell due to direct contact with core debris and events that bypass the containment. This is also true at Quad Cities. The head flooding system would, therefore, not be expected to have any significant impact on the overall risk. The potential for competing risks due to Reactor Building flooding is considered to eliminate any positive safety benefit.	Considering uncertainty and potential impacts from external events does not introduce any significant changes. No change to the screening criteria category.	N/A

Table 7-2
Revised Phase I SAMA Disposition (Assuming Maximum Averted Cost Risk of $500K)

Phase I SAMA ID number	SAMA title	Result of potential enhancement	Original / Revised Screening Criteria	Original Disposition	Revised Disposition Including Uncertainty and External Events	Phase II SAMA ID number
47	Enhance fire protection system and/or standby gas treatment system hardware and procedures.	SAMA would improve fission product scrubbing in severe accidents.	#4 - No significant safety benefit	Current Standby Gas Treatment Systems do not have sufficient capacity to handle the loads from severe accidents that result in a bypass or breach of the containment. Loads produced as a result of RPV or containment blowdown would require large filtering capacities. These filtered vented systems have been previously investigated and found not to provide sufficient cost benefit. Quad Cities has limited fire protection sprinkler systems in the Reactor Building. Use of these for fission product scrubbing in the R.B. could create competing risks associated with spray failures and flooding of equipment with very limited potential benefit.	Considering uncertainty and potential impacts from external events does not introduce any significant changes. No change to the screening criteria category.	N/A
51	Create a core melt source reduction system.	SAMA would provide cooling and containment of molten core debris. Refractory material would be placed underneath the reactor vessel such that a molten core falling on the material would melt and combine with the material. Subsequent spreading and heat removal from the vitrified compound would be facilitated, and concrete attack would not occur	#5 - Cost would be more than risk benefit	Core retention devices have been investigated in previous studies. IDCOR concluded that "core retention devices are not effective risk reduction devices for degraded core events". Other evaluations have shown the worth value for a core retention device to be on the order of $7000 compared to an estimated implementation cost of over $1 million.	The cost is considered to be greater than the upper bound maximum averted cost risk of $500K. No change to the screening criteria category.	N/A

Table 7-2
Revised Phase I SAMA Disposition (Assuming Maximum Averted Cost Risk of $500K)

Phase I SAMA ID number	SAMA title	Result of potential enhancement	Original / Revised Screening Criteria	Original Disposition	Revised Disposition Including Uncertainty and External Events	Phase II SAMA ID number
54	Install a secondary containment filtered vent.	SAMA would filter fission products released from primary containment.	#5 - Cost would be more than risk benefit	Secondary containment at Quad Cities makes extensive use of blow out panels to protect the structural integrity of the building in the event of internal pressure challenges such as steam line breaks in the reactor building or external pressure challenges such as tornadoes. Major structural redesign of the reactor building would be required to make the reactor building capable of retaining and processing a primary containment failure.	The cost is considered to be greater than the upper bound maximum averted cost risk of $500K. No change to the screening criteria category.	N/A
55	Install a passive containment spray system.	SAMA would provide redundant containment spray method without high cost.	#5 - Cost would be more than risk benefit.	See SAMAs 36 and 53. A passive system is another alternative enhancement for the Containment Spray function. See #36.	The cost is considered to be greater than the upper bound maximum averted cost risk of $500K. No change to the screening criteria category.	N/A
56	Strengthen primary/secondary containment.	SAMA would reduce the probability of containment overpressurization to failure.	#5 - Cost would be more than risk benefit	Reference 17 discusses the cost of increasing the containment pressure and temperature capacity, which is effectively strengthening the containment. This cost is estimated assuming the change is made during the design phase whereas for Quad Cities, the changes would have to be made as a retrofit. The cost estimated for the ABWR was $12 million and it is judged that retrofitting an existing containment would cost more. The cost of implementation for this SAMA exceeds the maximum averted cost-risk for Quad Cities.	The cost is considered to be greater than the upper bound maximum averted cost risk of $500K. No change to the screening criteria category.	N/A
57	Increase the depth of the concrete basemat or use an alternative concrete material to ensure melt-through does not occur.	SAMA would prevent basemat melt-through.	#5 - Cost would be more than risk benefit	Core retention devices have been investigated in previous studies. IDCOR concluded that "core retention devices are not effective risk reduction devices for degraded core events". Other evaluations have shown the worth value for a core retention device to be on the order of $7000 compared to an estimated implementation cost of over $1 million/site.	The cost is considered to be greater than the upper bound maximum averted cost risk of $500K. No change to the screening criteria category.	N/A

Table 7-2
Revised Phase I SAMA Disposition (Assuming Maximum Averted Cost Risk of $500K)

Phase I SAMA ID number	SAMA title	Result of potential enhancement	Original / Revised Screening Criteria	Original Disposition	Revised Disposition Including Uncertainty and External Events	Phase II SAMA ID number
58	Provide a reactor vessel exterior cooling system.	SAMA would provide the potential to cool a molten core before it causes vessel failure, if the lower head could be submerged in water.	#5 - Cost would be more than risk benefit	This has been estimated to cost $2.5 million and exceeds the maximum averted cost-risk for Quad Cities defined in Section F.4.7. ORNL [87] has performed thermal hydraulic calculations on BWR external cooling methods and determined that the current BWR RPV support skirt design makes it impractical to cool the RPV by external cooling to prevent RPV breach. Therefore, the modification would require RPV support skirt modification and reanalysis to allow the external cooling to be effective.	The cost is considered to be greater than the upper bound maximum averted cost risk of $500K. No change to the screening criteria category.	N/A
59	Construct a building to be connected to primary/secondary containment that is maintained at a vacuum.	SAMA would provide a method to depressurize containment and reduce fission product release.	#5 - Cost would be more than risk benefit	Based on engineering judgement, the cost of this enhancement is expected to greatly exceed the maximum averted cost risk for Quad Cities.	The cost is considered to be greater than the upper bound maximum averted cost risk of $500K. No change to the screening criteria category.	N/A
65	1.h. Simulator Training for Severe Accident	SAMA would lead to improved arrest of core melt progress and prevention of containment failure	#4 - No significant safety benefit Previously assessed by the NRC as not required to support Accident management.	Simulators could be upgraded and used to provide operator training for severe accidents; however, these scenarios are rare and the instruction time would compete with time required to train operators on more likely scenarios that are severe accident precursors. The benefit of simulator training is difficult to quantify as the results would be based on the improved reliability of human actions in the mitigation of severe accidents. Training can positively influence the values of HEPs, but the impact is small. In addition, the TSC would be manned in a severe accident evolution and could provide additional support by personnel familiar with the SAMGs.	Considering uncertainty and potential impacts from external events does not introduce any significant changes. No change to the screening criteria category.	N/A

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Revised Phase I SAMA Disposition (Assuming Maximum Averted Cost Risk of $500K)

Phase I SAMA ID number	SAMA title	Result of potential enhancement	Original / Revised Screening Criteria	Original Disposition	Revised Disposition Including Uncertainty and External Events	Phase II SAMA ID number
67	3.a. Larger Volume Containment	SAMA increases time before containment failure and increases time for recovery	#5 - Cost would be more than risk benefit	Enlargement of the containment would be similar in scope to the ABWR design change SAMA to implement a larger volume containment, but would likely exceed the $8 million estimate for that change as a retrofit would be required. This is greater than the maximum averted cost-risk defined in F.4.7.	The cost is considered to be greater than the upper bound maximum averted cost risk of $500K. No change to the screening criteria category.	N/A
69	3.c. Improved Vacuum Breakers (redundant valves in each line)	SAMA reduces the probability of a stuck open vacuum breaker.	#5 - Cost would be more than risk benefit	The Quad Cities plant has twelve (12) individual vacuum breaker lines with a single vacuum breaker in each line. Providing redundant vacuum breakers in each line would decrease the potential for vapor suppression failure and suppression pool bypass. This plant modification requires new valves, the structural changes to implement the modification, and the outage time to install. Based on the PRA results that vapor suppression failure and pool bypass are negligible risk contributors and the apparent extremely high cost, this proposed SAMA is not considered cost effective.	Considering uncertainty and potential impacts from external events does not introduce any changes to the original disposition (Vapor suppression failures are not significant contributors to external events). No change to the screening criteria category.	N/A
94	Use fuel cells instead of lead-acid batteries.	SAMA would extend DC power availability in an SBO.	#6 - Retain	Improving battery capacity may be cost beneficial for Quad Cities. Further extension of battery life with fuel cells is estimated to have a small impact on the Quad Cities residual risk profile.	Still retained.	3

Table 7-2
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Phase I SAMA ID number	SAMA title	Result of potential enhancement	Original / Revised Screening Criteria	Original Disposition	Revised Disposition Including Uncertainty and External Events	Phase II SAMA ID number
96	Improve 4.16-kV bus cross-tie ability.	Enhance procedures to direct 4kV bus cross-tie. If this procedural step already exists, investigate installation of hardware that would perform an *automatic cross-tie* to the opposite 4kV bus given failure of the dedicated diesel.	#6 - Retain	Manual cross-tie between AC buses is proceduralized for certain buses depending on the available AC source (e.g., offsite power, SBO D/G). These cross-ties are effective and further risk reduction from auto cross-tie is of marginal benefit, and could produce competing risks. Automatic cross-tie could be implemented at Quad Cities. In addition, procedures could be developed that would allow the *following cross-ties to be performed:* -Bus 14-1 to Bus 24-1 from EDG 1 -Bus 24-1 to Bus 14-1 from EDG 2 -EDG 1/2 to Buses 13-1 and 23-1	Still retained.	4
107	Install gas turbine generator.	SAMA would improve onsite AC power reliability by providing a redundant and diverse emergency power system.	#5 - Cost would be more than risk benefit	The cost of installing a diverse, redundant, gas turbine generator is similar in scope to installing a new diesel generator. The cost of installing an additional diesel generator has been estimated at over $20 million in Reference 19. This cost of implementation for this SAMA greatly exceeds the maximum averted cost-risk for Quad Cities defined in Section F.4.7. In addition, Quad Cities already has five diverse on-site AC power sources. Installing a gas turbine would provide minimal safety benefit.	The cost is considered to be greater than the upper bound maximum averted cost risk of $500K. No change to the screening criteria category.	N/A
108	Create a backup source for diesel cooling. (Not from existing system)	This SAMA would provide a redundant and diverse source of cooling for the diesel generators, which would contribute to enhanced diesel reliability.	#6 - Retain	*An additional EDG cooling source may be* cost beneficial for Quad Cities. This load path also includes ECCS room cooling.	*Still retained*	5

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Phase I SAMA ID number	SAMA title	Result of potential enhancement	Original / Revised Screening Criteria	Original Disposition	Revised Disposition Including Uncertainty and External Events	Phase II SAMA ID number
110	Provide a connection to an alternate source of offsite power.	SAMA would reduce the probability of a loss of offsite power event.	#5 - Cost would be more than risk benefit	Offsite power lines would be exposed to severe weather at some point along the offsite power line route. While the actual cost of this SAMA will vary depending on site characteristics, the cost of connecting to an alternate source of power has been estimated at >$25 million for another commercial US nuclear plant. Implementing this SAMA at Quad Cities is considered to be within the same order of magnitude and exceeds the maximum averted cost-risk for Quad Cities as defined in Section F.4.7. In addition, Quad Cities has multiple offsite sources and multiple, diverse on-site AC power sources. Providing additional AC power sources would provide minimal safety benefit.	The cost is considered to be greater than the upper bound maximum averted cost risk of $500K. No change to the screening criteria category.	N/A
111	Bury offsite power lines.	SAMA could improve offsite power reliability, particularly during severe weather.	#5 - Cost would be more than risk benefit	While the actual cost of this SAMA will vary depending on site characteristics, the cost of burying offsite power lines has been estimated at a cost significantly greater than $25 million for another commercial US nuclear plant. Implementing this SAMA at Quad Cities is considered to be within the same order of magnitude and exceeds the maximum averted cost-risk for Quad Cities as defined in Section F.4.7.	The cost is considered to be greater than the upper bound maximum averted cost risk of $500K. No change to the screening criteria category.	N/A
114	Provide DC power to the 120/240-V vital AC system from the Class 1E station service battery system instead of its own battery.	SAMA would increase the reliability of the 120-VAC Bus.	#4 - No significant safety benefit	1) Loss of 120V AC is not an Initiating Event 2) 120 VAC is not a risk significant support system	Considering uncertainty and potential impacts from external events does not introduce any significant changes. No change to the screening criteria category.	N/A

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Phase I SAMA ID number	SAMA title	Result of potential enhancement	Original / Revised Screening Criteria	Original Disposition	Revised Disposition Including Uncertainty and External Events	Phase II SAMA ID number
121	9.f. Improved Uninterruptable Power Supplies	SAMA would provide increased reliability of power supplies supporting front-line equipment, thus reducing core damage and release frequencies.	#4 - No significant safety benefit	1) Loss of 120V AC is not an initiating Event 2) 120 VAC is not a risk significant support system	Considering uncertainty and potential impacts from external events does not introduce any significant changes. No change to the screening criteria category.	N/A
125	10.a. Dedicated DC Power Supply	This SAMA addresses the use of a diverse DC power system such as an additional battery or fuel cell for the purpose of providing motive power to certain components (e.g., RCIC).	#5 - Cost would be more than risk benefit	The cost of implementation for this mod is estimated at $3 million, which is greater than the maximum averted cost-risk for Quad Cities as defined in Section F.4.7. See also SAMAs 93, 94, 97, 98, 99, and 100.	The cost is considered to be greater than the upper bound maximum averted cost risk of $500K. No change to the screening criteria category.	N/A
130	Add an automatic bus transfer feature to allow the automatic transfer of the 120V vital AC bus from the on-line unit to the standby unit	Plants are typically sensitive to the loss of one or more 120V vital AC buses. Manual transfers to alternate power supplies could be enhanced to transfer automatically.	#4 - No significant safety benefit	1) Loss of 120V AC is not an initiating Event 2) 120 VAC is not a risk significant support system	Considering uncertainty and potential impacts from external events does not introduce any significant changes. No change to the screening criteria category.	N/A
131	Provide procedures for (a) bypassing major DC buses; (b) locally starting equipment	This SAMA would allow for powering specific loads given a DC bus failure and/or the ability to start equipment locally that normally requires DC power for a control room start.	#6 - Retain	While DC buses are reliable, procedure changes may be cost beneficial given the importance of DC power.	Still retained.	6
132	Provide procedures to allow cross-tie of the 1/2 EDG to a bus which can supply the SSMP (14-1, 24-1, or 31)	This would provide additional diversity in the SSMP's power supply.	#5 - Cost would be more than risk benefit	A procedure change may be a cost beneficial enhancement for Quad Cities. However, the ability to cross-tie among divisions has so many competing risks and requires hardware changes that make this SAMA unacceptable given the low maximum averted for Quad Cities.	Additionally, the dominant failure mechanisms for the SSMP do not involve electrical or electrical support failures. As such, implementation of such a procedure would have minimal impact on the CDF results. No change to the screening criteria category.	N/A

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Phase I SAMA ID number	SAMA title	Result of potential enhancement	Original / Revised Screening Criteria	Original Disposition	Revised Disposition Including Uncertainty and External Events	Phase II SAMA ID number
141	Locate residual heat removal (RHR) inside of containment.	SAMA would prevent intersystem LOCA (ISLOCA) out the RHR pathway.	#5 - Cost would be more than risk benefit	Competing risks associated with such a design are manifold and would require extensive analysis to demonstrate capability. For an existing plant, the cost of moving an entire system is judged to greatly exceed the maximum averted cost-risk for Quad Cities as defined in Section F.4.7.	The cost is considered to be greater than the upper bound maximum averted cost risk of $500K. No change to the screening criteria category.	N/A
142	Install additional instrumentation for ISLOCAs.	SAMA would decrease ISLOCA frequency by installing leak monitoring instruments in between the first two pressure isolation valves on low-pressure inject lines and RHR suction lines.	#4 - No significant safety benefit	Related to mitigation of an ISLOCA. Per IN-92-36 and its additional supplement, ISLOCA contributes little risk for BWRs. For Quad Cities, ISLOCA and Large Break Outside Containment have CDF based Risk Reduction Worth values of 1.005 and 1.000, respectively. ISLOCA sequences comprise less than 1% of the LERF at Quad Cities.	Considering uncertainty and potential impacts from external events does not introduce any changes to the original disposition (ISLOCAs are not significant contributors to external events). No change to the screening criteria category.	N/A
143	Increase frequency for valve leak testing.	SAMA could reduce ISLOCA frequency.	#4 - No significant safety benefit	The PIV interface valves at Quad Cities are leak tested. Related to mitigation of an ISLOCA. Per IN-92-36 and its additional supplement, ISLOCA contributes little risk for BWRs. For Quad Cities, ISLOCA and Large Break Outside Containment have CDF based Risk Reduction Worth values of 1.005 and 1.000, respectively. ISLOCA sequences comprise less than 1% of the LERF at Quad Cities. Competing Risk: Valve leak testing may actually increase risk because on-line valve manipulation is required.	Considering uncertainty and potential impacts from external events does not introduce any changes to the original disposition (ISLOCAs are not significant contributors to external events). No change to the screening criteria category.	N/A

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Phase I SAMA ID number	SAMA title	Result of potential enhancement	Original / Revised Screening Criteria	Original Disposition	Revised Disposition Including Uncertainty and External Events	Phase II SAMA ID number
144	Improve operator training on ISLOCA coping.	SAMA would decrease ISLOCA effects.	#4 - No significant safety benefit	Related to mitigation of an ISLOCA. Per IN-92-36 and its additional supplement, ISLOCA contributes little risk for BWRs. For Quad Cities, ISLOCA and Large Break Outside Containment have CDF based Risk Reduction Worth values of 1.005 and 1.000, respectively. ISLOCA sequences comprise less than 1% of the LERF at Quad Cities. In addition, the Quad Cities EOPs provide secondary containment monitoring parameters which include room specific temperature, room specific radiation, vent radiation, and room specific water level. The instrumentation and procedural guidance help locate and isolate breaks which have bypassed primary containment.	Considering uncertainty and potential impacts from external events does not introduce any changes to the original disposition (ISLOCAs are not significant contributors to external events). No change to the screening criteria category.	N/A
146	Provide leak testing of valves in ISLOCA paths.	SAMA would help reduce ISLOCA frequency. At Kewaunee Nuclear Power Plant, four MOVs isolating RHR from the RCS were not leak tested.	#4 - No significant safety benefit	Related to mitigation of an ISLOCA. Per IN-92-36 and its additional supplement, ISLOCA contributes little risk for BWRs. For Quad Cities, ISLOCA and Large Break Outside Containment have CDF based Risk Reduction Worth values of 1.005 and 1.000, respectively. ISLOCA sequences comprise less than 1% of the LERF at Quad Cities. Competing Risk: Valve leak testing may actually increase risk because on-line valve manipulation is required.	Considering uncertainty and potential impacts from external events does not introduce any changes to the original disposition (ISLOCAs are not significant contributors to external events). No change to the screening criteria category.	N/A

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Phase I SAMA ID number	SAMA title	Result of potential enhancement	Original / Revised Screening Criteria	Original Disposition	Revised Disposition Including Uncertainty and External Events	Phase II SAMA ID number
148	Ensure all ISLOCA releases are scrubbed.	SAMA would scrub all ISLOCA releases. One example is to plug drains in the break area so that the break point would be covered with water.	#4 - No significant safety benefit	ISLOCA and Large Break Outside Containment have CDF based Risk Reduction Worth values of 1.005 and 1.000, respectively. ISLOCA sequences comprise less than 1% of the LERF at Quad Cities. The cost of performing the analysis to identify all ISLOCA pathways and to ensure that any physical modifications implemented to mitigate ISLOCAs are not detrimental to the plant (e.g., cause flooding hazards) combined with the cost of installing the required equipment is judged to greatly exceed any benefit. Additionally, the suggested enhancement of plugging drain lines would not guarantee a release would be scrubbed as the release may occur prior to the submergence of the break. Room flooding equipment and waterproofing of mitigative components would be required to make this SAMA potentially effective. Such changes would be extremely costly and potential competing risk appears to significantly outweigh any possible safety benefit.	Considering uncertainty and potential impacts from external events does not introduce any changes to the original disposition (ISLOCAs are not significant contributors to external events). No change to the screening criteria category.	N/A
149	Add redundant and diverse limit switches to each containment isolation valve.	SAMA could reduce the frequency of containment isolation failure and ISLOCAs through enhanced isolation valve position indication.	#4 - No significant safety benefit	Related to mitigation of an ISLOCA. Per IN-92-36 and its additional supplement, ISLOCA contributes little risk for BWRs. For Quad Cities, ISLOCA and Large Break Outside Containment have CDF based Risk Reduction Worth values of 1.005 and 1.000, respectively. ISLOCA sequences comprise less than 1% of the LERF at Quad Cities.	Considering uncertainty and potential impacts from external events does not introduce any changes to the original disposition. No change to the screening criteria category.	N/A

Table 7-2
Revised Phase I SAMA Disposition (Assuming Maximum Averted Cost Risk of $500K)

Phase I SAMA ID number	SAMA title	Result of potential enhancement	Original / Revised Screening Criteria	Original Disposition	Revised Disposition Including Uncertainty and External Events	Phase II SAMA ID number
151	8.e. Improved MSIV Design	This SAMA would decrease the likelihood of containment bypass scenarios.	#4 - No significant safety benefit	There is no evidence of poor MSIV performance. Redundant MSIVs are designed to isolate on severe accidents that could lead to radionuclide release and bypass containment. These include breaks outside containment. The MSIVs are leak tested to ensure their adequacy. The Maintenance Rule program monitors the performances of the MSIVs providing early feedback on any degradation. The PRA has determined that the risk contribution from MSIV failures to isolate is very small.	Considering uncertainty and potential impacts from external events does not introduce any changes to the original disposition. No change to the screening criteria category.	N/A
156	Modify swing direction of doors separating turbine building basement from areas containing safeguards equipment.	SAMA would prevent flood propagation, for a plant where internal flooding from turbine building to safeguards areas is a concern.	#4 - No significant safety benefit	Quad Cities plant is not susceptible to flood propagation from the turbine building to adjacent buildings with safety equipment. Flooding from Turbine Hall into adjacent buildings considered to have negligible impact. Electrical Equipment (MCCs, diesel generators, batteries, SSMP) are located at the 595' El. or above. There are Turbine Building access "roll-up" doors at the 595' El. Flooding is not expected to reach the 595' El.; if it does, then discharge to the outside should preclude any further rise.	Considering uncertainty and potential impacts from external events does not introduce any changes to the original disposition. No change to the screening criteria category.	N/A

Table 7-2
Revised Phase I SAMA Disposition (Assuming Maximum Averted Cost Risk of $500K)

Phase I SAMA ID number	SAMA title	Result of potential enhancement	Original / Revised Screening Criteria	Original Disposition	Revised Disposition Including Uncertainty and External Events	Phase II SAMA ID number
158	Implement internal flood prevention and mitigation enhancements.	This SAMA would reduce the consequences of internal flooding.	#5 - Cost would be more than risk benefit.	The Quad Cities Internal Flooding Analysis states that there do not appear to be any flood specific response procedures for catastrophic flood events. The existing procedures appear to be completely adequate for small leaks; however, they are judged not to provide specific directions to respond to large flow rate breaks. As a result, relatively high failure probabilities are estimated for the mitigative actions required to prevent extensive damage. Internal flood enhancements would include: - Curbs around the corner room stairwells to the RHR compartments - Coping procedures for SW floods in the Reactor Building For example, a specific pipe break scenario has been postulated that would disable 4kV buses 13 and 14. Given the consequential failure of Unit 1 TBCCW, several compensatory options exist: The internal flood evaluation in the IPE calculated a CDF that would be less than 10% of the current Quad Cities CDF. This translates into approximately $10,000 as the maximum cost that can be shown to be cost beneficial. No procedures or plant modification is judged to be possible for this cost and therefore this SAMA is found not to be cost beneficial.	Considering uncertainty and potential impacts from external events does not introduce any changes to the original disposition. No change to the screening criteria category.	N/A

Table 7-2
Revised Phase I SAMA Disposition (Assuming Maximum Averted Cost Risk of $500K)

Phase I SAMA ID number	SAMA title	Result of potential enhancement	Original / Revised Screening Criteria	Original Disposition	Revised Disposition Including Uncertainty and External Events	Phase II SAMA ID number
162	Review Circulating Water Pump Auto Trip procedure to determine its applicability to a condenser pit flooding scenario	This is a Quad Cities specific SAMA that is related to the procedural direction to start the standby Circulating Water pump on trip of the initially running pump given high Condenser Pit level. Use of the current procedure may exacerbate the flooding and result in an overflow into the Turbine Basement (which contains the condensate pumps and RHRSW vaults).	#4 - No significant safety benefit	Risk contribution is so low due to this postulated scenario that cost cannot be justified.	Considering uncertainty and potential impacts from external events does not introduce any changes to the original disposition. No change to the screening criteria category.	N/A
163	Consider dual unit flood effects in the EOPs	The current Quad Cities EOPs (QGAs) do not consider the impact of a flooding event in the opposite unit on the equipment of the given unit. A flood in certain compartments of one unit will result in a challenge to equipment in the opposite unit due to plant configuration. Updating the QGAs to account for the potential loss of equipment given a flood in the opposite unit will allow the operators to prepare for a scram and plan for the use of appropriate alternative systems.	#4 - No significant safety benefit	Quad Cities flood induced risk is quite low and that due to any dual unit issues negligible. Changes cannot be implemented on a cost beneficial basis.	Considering uncertainty and potential impacts from external events does not introduce any changes to the original disposition. No change to the screening criteria category.	N/A

Table 7-2
Revised Phase I SAMA Disposition (Assuming Maximum Averted Cost Risk of $500K)

Phase I SAMA ID number	SAMA title	Result of potential enhancement	Original / Revised Screening Criteria	Original Disposition	Revised Disposition Including Uncertainty and External Events	Phase II SAMA ID number
164	Examine the potential for RHRSW vault failure and consequential Turbine Basement flooding	The RHRSW vaults at Quad Cities contain piping from the discharge from one or more other RHRSW pumps. A break in the piping not co-located with the pump will flood the RHRSW vault and result in an internal pressure build up. The potential exists for the vault to collapse and result in Turbine Basement flooding. Resolution of this SAMA would decrease the contribution of internal flooding in this area.	#5 - Cost would be more than risk benefit.	The internal flood probabilistic analysis includes the quantification of the RHRSW pipe breaks and the resulting quantification shows that the subject insight has a negligible impact on plant risk. The estimated cost of structural analysis, structural changes, instrument changes, or procedure changes would not be cost justified, i.e., would be far in excess of the total internal flood risk contribution >>$10,000.	Considering uncertainty and potential impacts from external events does not introduce any changes to the original disposition. No change to the screening criteria category.	N/A
170	Install a new condensate storage tank (CST)	Either replace the existing tank with a larger one, or install a back-up tank.	#5 – Cost would be more than risk benefit	Installation of an additional CST may be a cost beneficial means of reducing risk at Quad Cities. The availability of significantly larger CST volume could be used by LPCI or CS to provide continuous RPV injection regardless of torus conditions.	The cost is considered to be greater than the upper bound maximum averted cost risk of $500K. No change to the screening criteria category.	N/A
178	Install an independent diesel generator for the CST make-up pumps	This SAMA would allow continued inventory make-up to the CST during an SBO.	#4 - No significant safety benefit	HPCI and RCIC are the turbine driven injection systems for Quad Cities. The CCSTs each have a nominal water supply of 260,000 gallons and the reserved volume (only accessible by SSMP, HPCI, and RCIC) is 90,000 gallons. Given a battery life of 4 hours (required for HPCI/RCIC operation) and an initial volume of 90,000 gallons, no additional water source would be required for injection during the 4 hour SBO mission time. Minimal benefit would be gained from this SAMA. Similar item is addressed under proposed SAMA #60.	Considering uncertainty and potential impacts from external events does not introduce any significant changes. No change to the screening criteria category.	N/A

Table 7-2
Revised Phase I SAMA Disposition (Assuming Maximum Averted Cost Risk of $500K)

Phase I SAMA ID number	SAMA title	Result of potential enhancement	Original / Revised Screening Criteria	Original Disposition	Revised Disposition Including Uncertainty and External Events	Phase II SAMA ID number
191	Upgrade Chemical and Volume Control System to mitigate small LOCAs.	For a plant like the AP600 where the Chemical and Volume Control System cannot mitigate a Small LOCA, an upgrade would decrease the Small LOCA CDF contribution.	#5 - Cost would be more than risk benefit	A potential functional equivalent for Quad Cities would be the enhancement of the RWCU system such that injection flow rates on the order of 1000 gpm were possible. This change is considered to be similar in function, scope, and cost to SAMA 185 ($5-$10 million) with the exception of the independent power source. However, new power circuits and wiring would likely be needed for the larger pumps. The low end of the cost of implementation estimate ($5 million) is judged to be applicable for this SAMA, which is greater than the maximum averted cost risk for Quad Cities as defined in Section F.4.7.	The cost is considered to be greater than the upper bound maximum averted cost risk of $500K. No change to the screening criteria category.	N/A
194	Replace 2 of the 4 safety injection (SI) pumps with diesel-powered pumps.	This SAMA would reduce the SI system common cause failure probability. This SAMA was intended for the System 80+, which has four trains of SI.	#4 - No significant safety benefit Revised to: #5 – Cost would be more than risk benefit	Quad Cities has a diverse set of injection systems and more than one method of containment heat removal. Common cause failure of the 4 train RHR system is a low contributor to risk and removing the 4/4 system failures would have minimal impact on the results. The CCF of all four RHR pumps to run (1RHPM1ABCD---XCC) has a Risk Reduction Worth of 1.000 (with respect to CDF). The CCF of all four RHR pumps to fail to start (1RHPM1ABCD---ACC) does not appear in any CDF cutsets above the truncation limit for the plant model and would not impact the results if it were improved.	Installation of independent RHR / RHRSW pumps that could provide an alternate means of containment heat removal would be beneficial to reduce the Fire CDF that is largely dominated by loss of decay heat removal scenarios. However, the cost to implement such a system is considered to be greater than the upper bound maximum averted cost risk of $500K.	N/A

Table 7-2
Revised Phase I SAMA Disposition (Assuming Maximum Averted Cost Risk of $500K)

Phase I SAMA ID number	SAMA title	Result of potential enhancement	Original / Revised Screening Criteria	Original Disposition	Revised Disposition Including Uncertainty and External Events	Phase II SAMA ID number
196	Raise high pressure core injection/reactor core isolation cooling backpressure trip setpoints	This SAMA would ensure high pressure core injection/reactor core isolation cooling availability when high suppression pool temperatures exist.	#4 - No significant safety benefit	The HPCI high backpressure trip is already set at a pressure above the containment ultimate pressure; thus, raising the trip limit would have very limited impact. The RCIC trip limit could be increased or bypassed, but the benefit would also be small because RPV depressurization is required before containment conditions are above these back pressure set points. Therefore, no benefit is gained from increasing these numerical values.	Considering uncertainty and potential impacts from external events does not introduce any significant changes. No change to the screening criteria category.	N/A
197	Improve the reliability of the automatic depressurization system.	This SAMA would reduce the frequency of high pressure core damage sequences.	#5 - Cost would be more than risk benefit	High pressure melt scenarios are significant contributors to the Quad Cities CDF. The SAMA is interpreted to mean improved reliability of the ERVs and Target Rock SRVs and their support systems. A plant modification to eliminate dependence on DC power to increase the success probability of these valves would reduce the high pressure injection accident classes of IA and IE. No such design is currently available. This would require a research and development project.	Considering uncertainty and potential impacts from external events does not introduce any significant changes. No change to the screening criteria category.	N/A
201	Increase available net positive suction head (NPSH) for injection pumps.	SAMA increases the probability that these pumps will be available to inject coolant into the vessel by increasing the available NPSH for the injection pumps.	#5 - Cost would be more than risk benefit	Requires major plant changes such as new RHR pumps, moving the RHR pumps, a new suppression pool design, a larger CCST (only applicable for injection phase), or an additional containment cooling system. The cost of these changes would exceed the maximum averted cost-risk for Quad Cities as defined in Section F.4.7.	The cost is considered to be greater than the upper bound maximum averted cost risk of $500K. No change to the screening criteria category.	N/A

Table 7-2
Revised Phase I SAMA Disposition (Assuming Maximum Averted Cost Risk of $500K)

Phase I SAMA ID number	SAMA title	Result of potential enhancement	Original / Revised Screening Criteria	Original Disposition	Revised Disposition Including Uncertainty and External Events	Phase II SAMA ID number
202	Modify Reactor Water Cleanup (RWCU) for use as a decay heat removal system and proceduralize use.	SAMA would provide an additional source of decay heat removal.	#5 - Cost would be more than risk benefit	In order to make RWCU a viable heat removal system, the piping, pumps, heat exchangers, and power sources would have to be upgraded. This SAMA is considered to be similar in scope to SAMA 191. The cost of implementation for such a change (approximately $5 million) is greater than the maximum averted cost-risk for Quad Cities.	The cost is considered to be greater than the upper bound maximum averted cost risk of $500K. No change to the screening criteria category.	N/A
208	2.a. Passive High Pressure System	SAMA will improve prevention of core melt sequences by providing additional high pressure capability to remove decay heat through an isolation condenser type system	#5 - Cost would be more than risk benefit	The cost of this enhancement has been estimated to be $1.7 million in Reference 17. This is greater than the maximum averted cost-risk for Quad Cities as defined in Section F.4.7.	The cost is considered to be greater than the upper bound maximum averted cost risk of $500K. No change to the screening criteria category.	N/A
209	2.c. Suppression Pool Jockey Pump	SAMA will improve prevention of core melt sequences by providing a small makeup pump to provide low pressure decay heat removal from the RPV using the suppression pool as a source of water.	#5 - Cost would be more than risk benefit	From a review of the contributors to the Quad Cities risk profile it is found that the availability of low pressure pumps for RPV make up is not a dominant contributor. The low pressure pump availability for RPV injection is a negligible contributor to the risk profile. The expense of adding another low pressure injection system without introducing severe competing risks is expected to be high. It can be concluded that the cost will not be able to be justified.	Loss of all low pressure injection is also not a dominant contributor to the external events analysis. As such, considering uncertainty and potential impacts from external events does not introduce any significant changes. No change to the screening criteria category.	N/A
214	4.c. High Flow Suppression Pool Cooling	SAMA would improve suppression pool cooling for ATWS response.	#5 - Cost would be more than risk benefit	Increasing the capabilities of suppression pool would require new pumps, heat exchangers, piping, and other equipment. The implementation cost of this change is considered to be approximately equivalent to SAMA 35 ($5.8 million) and is screened from further review as it is significantly greater than the maximum averted cost-risk for Quad Cities as defined in Section F.4.7.	The cost is considered to be greater than the upper bound maximum averted cost risk of $500K. No change to the screening criteria category.	N/A

Table 7-2
Revised Phase I SAMA Disposition (Assuming Maximum Averted Cost Risk of $500K)

Phase I SAMA ID number	SAMA title	Result of potential enhancement	Original / Revised Screening Criteria	Original Disposition	Revised Disposition Including Uncertainty and External Events	Phase II SAMA ID number
216	Delete High DW Pressure Signal from SDC isolation	This SAMA would allow the initiation of SDC when the drywell is at elevated pressures.	#6 - Retain	SDC could be used for DHR in conditions where it is currently precluded from use. Removal of this logic is not a cost beneficial modification but would be a safety enhancement if justified on other bases.	Still retained.	7
217	Use SSMP to provide injection to Unit 1 and Unit 2 simultaneously	The SSMP provides injection to one unit at a time. Injection to both units simultaneously could be beneficial in cases where only SSMP injection is available. This would eliminate the need to alternate injection between the units.	#4 - No significant safety benefit	This SAMA only applies to dual unit initiators. For single unit initiators, SSMP can be dedicated to the shutdown unit. The SSMP flow rate is sufficient to support a single unit for adequate core cooling if it is the sole injection source and the event resembles an MSIV closure from full power. In that case, sharing of SSMP is not an effective option. For other less severe cases (e.g., reduced power operation, other injection sources available), the SSMP is sufficient to refill the RPV to Level 8. Therefore, the number of SSMP "cycles" to alternate between units is relatively low, i.e., approximately ten over the 24-hour mission time. The SSMP can be easily switched from one unit to the other through the manipulation of two MOVs. In addition to the MOVs, there are four check valves that also need to open per "cycle." This results in a small change in SSMP failure probability of 6.4E-3[2] (12% of the SSMP unavailability not counting the support systems) and a negligible change to the Quad Cities risk profile.	Considering uncertainty and potential impacts from external events does not introduce any significant changes. No change to the screening criteria category.	N/A

[2] Consistent with the assessment of subsequent MOV and check valve movements the failure probability is set at a factor of ten lower than the initial failure probability on a per demand (cycle) basis.

Table 7-2
Revised Phase I SAMA Disposition (Assuming Maximum Averted Cost Risk of $500K)

Phase I SAMA ID number	SAMA title	Result of potential enhancement	Original / Revised Screening Criteria	Original Disposition	Revised Disposition Including Uncertainty and External Events	Phase II SAMA ID number
218	Install a high level SSMP pump trip to avoid water solid operation of the RPV.	This would help prevent inadvertent overpressurization of the RPV.	#5 - Cost would be more than risk benefit	The impact of this SAMA is very low. Water solid over-pressurization is currently modeled in the PSA to be a negligible contributor to risk.	Considering uncertainty and potential impacts from external events does not introduce any significant changes. No change to the screening criteria category.	N/A
219	Develop procedures to control Feedwater flow without 125 VDC power to prevent tripping Feedwater on High/Low level	This SAMA increases the functionality of Feedwater in loss of DC scenarios and increases the probability of successful level control.	#6 - Retain	Evaluate the benefit of improved Feedwater level control given loss of DC.	Still retained.	8
220	Remove Loop Select Logic	In the event that there is no break in the recirc loops and there is a Loop "B" injection path failure, the Loop "A" injection path is precluded from use. Removal of the LPCI Loop Select Logic or installation of a bypass switch would allow use of the "A" loop for injection in the event of a "B" injection path failure.	#6 - Retain	Evaluate the benefit removal or bypass of LPCI Loop Select Logic.	Still retained.	9
221	Demonstrate RCIC operability following depressurization	This SAMA would increase the operators' options for low pressure vessel injection.	#6 - Retain	Determine if demonstrating the operability of RCIC after depressurization is a cost-beneficial effort. Alternatively, Emergency depressurization could be directed to be stopped at 100 psig.	Still retained.	10

Table 7-2
Revised Phase I SAMA Disposition (Assuming Maximum Averted Cost Risk of $500K)

Phase I SAMA ID number	SAMA title	Result of potential enhancement	Original / Revised Screening Criteria	Original Disposition	Revised Disposition Including Uncertainty and External Events	Phase II SAMA ID number
225	Allow cross connection of uninterruptable compressed air supply to opposite unit.	SAMA would increase the ability to vent containment using the hardened vent.	#3 - Already implemented at Quad Cities Revised to: #6 - Retain	An inter-unit Instrument Air crosstie valve already exists at Quad Cities and can be opened locally. A connection to the Service Air System also exists for each unit (the unit Service Air compressors output to a common header such that the two units are normally fully cross-tied). A plant modification is already approved to increase instrument air reliability for such things as venting for long-term sequences, by providing for connection of a truck-mounted compressor. Unit 1 & 2 Instrument Air Mods (EC 335806 and EC335807, respectively) add ability to tie in truck-mounted IA compressor to IA system to allow opening of containment vents in cases of extended loss of IA/containment heat removal. The modification to be installed by 12/31/02 provides the necessary piping and supports to permit temporary hook-up of a 1600 CFM, diesel Driven, Air Compressor to a 3" NPT Threaded connection on the Instrument Air System. Several area rental facilities have been contacted and all have stated that they have the ability to provide a temporary compressor within 12 hours of notification regardless of the day or time. With this hookup installed, it can reasonably be expected that the system can be pressurized well before the containment venting valves are required to operate.	Mods EC 335806 and EC 335807 have been cancelled due to large scope of needed equipment changes. Now pursuing hookup of temporary compressor to existing IA connections. A technical evaluation (EC 339420) has been performed that includes the necessary requirements for the temporary air hose, including a description of the flow path and the connections to the air header. This SAMA is now retained to determine the potential cost benefit of such a change.	17

Table 7-2
Revised Phase I SAMA Disposition (Assuming Maximum Averted Cost Risk of $500K)

Phase I SAMA ID number	SAMA title	Result of potential enhancement	Original / Revised Screening Criteria	Original Disposition	Revised Disposition Including Uncertainty and External Events	Phase II SAMA ID number
237	Bypass MSIV isolation in Turbine Trip ATWS scenarios	SAMA will afford operators more time to perform actions. The discharge of a substantial fraction of steam to the main condenser (i.e., as opposed to into the primary containment) affords the operator more time to perform actions (e.g., SLC injection, lower water level, depressurize RPV) than if the main condenser was unavailable, resulting in lower human error probabilities	#6 - Retain	Bypass of MSIV isolation is procedurally directed in the EOPs; however, this action requires the use of jumpers. A dedicated switch for bypassing the low level interlock would be desirable.	Still retained. This was inadvertently not transferred to Phase II in the ER. Now retained and subject to analysis.	16
242	Diversify the explosive valve operation	An alternate means of opening a pathway to the RPV for SBLC injection would improve the success probability for reactor shutdown.	#6 - Retain	SBLC injection failure is a dominant contributor to ATWS mitigation failure. Evaluate SBLC system improvements.	Still retained	11
243	Enrich Boron	The increased boron concentration will reduce the time required to achieve the shutdown concentration. This will provide increased margin in the accident timeline for successful operator activation of SBLC.	#6 - Retain	Increasing the boron concentration for SBLC may be a cost effective means of reducing ATWS risk.	Still retained.	12

Table 7-2
Revised Phase I SAMA Disposition (Assuming Maximum Averted Cost Risk of $500K)

Phase I SAMA ID number	SAMA title	Result of potential enhancement	Original / Revised Screening Criteria	Original Disposition	Revised Disposition Including Uncertainty and External Events	Phase II SAMA ID number
245	Create/enhance RCS depressurization ability	With either a new depressurization system, or with existing PORVs, head vents, and secondary side valve, RCS depressurization would allow earlier low pressure ECCS injection. Even if core damage occurs, low RCS pressure would alleviate some concerns about high pressure melt ejection.	#5 - Cost would be more than risk benefit	PWR issue related to the limited depressurization capability of the PWR. In addition, reference 19 estimates the cost of this SAMA to range between $500,000 and $4.6 million. For Quad Cities, more effective depressurization capabilities would require significant hardware changes and/or additions on top of the analysis that would be required to implement the change. The cost estimate for the modification is considered to be on the high end of the range provided in Reference 19. The cost of implementation for this SAMA is judged to greatly exceed the maximum averted cost-risk for Quad Cities as defined in Section F.4.7.	The cost is considered to be greater than the upper bound maximum averted cost risk of $500K. No change to the screening criteria category.	N/A
249	Install secondary side guard pipes up to the MSIVs	This SAMA would prevent secondary side depressurization should a steam line break occur upstream of the main steam isolation valves. This SAMA would also guard against or prevent consequential multiple SGTR following a Main Steam Line Break event.	#5 - Cost would be more than risk benefit	This is primarily a PWR issue. The steam lines for a BWR inside the inboard MSIV are completely within the containment requiring no guard pipe. Between the two MSIVs is a very short length of pipe that contributes a negligible amount to the CDF and LERF. The addition of a guard pipe to the steam tunnel for the short pipe length is judged to be very expensive and substantially in excess of any potential benefit associated with risk reduction.	Considering uncertainty and potential impacts from external events does not introduce any significant changes. No change to the screening criteria category.	N/A
250	Install digital large break LOCA protection	Upgrade plant instrumentation and logic to improve the capability to identify symptoms/precursors of a large break LOCA (leak before break).	#5 - Cost would be more than risk benefit	Large break LOCA risk is low. Upgraded instrumentation is unproven, benefit is not known, cost is highly uncertain. The implementation could not be realistically justified.	Considering uncertainty and potential impacts from external events does not introduce any significant changes. No change to the screening criteria category.	N/A

Table 7-2
Revised Phase I SAMA Disposition (Assuming Maximum Averted Cost Risk of $500K)

Phase I SAMA ID number	SAMA title	Result of potential enhancement	Original / Revised Screening Criteria	Original Disposition	Revised Disposition Including Uncertainty and External Events	Phase II SAMA ID number
255	Increase seismic ruggedness of plant components.	SAMA would increase the availability of necessary plant equipment during and after seismic events.	#3 - Already implemented at Quad Cities	Refer to SAMA 251. Seismic issues were examined in the Quad Cities IPEEE and the cost-effective means of reducing plant risk were implemented as part of the program. These changes include: Replacing mercury switches in the Fire Protection System Improving MCC mounting and anchor welds Enhancing battery restraints	Also see Response 6(b).	N/A
260	1.e. Improved Accident Management Instrumentation	SAMA will improve prevention of core melt sequences by making operator actions more reliable.	#5 - Cost would be more than risk benefit	The risk as measured by CDF, LERF, and population dose is low. The instrumentation available to the operating crew at Quad Cities is comparable to that available at other BWRs. Based on a review of the accident sequences that contribute to the Quad Cities risk profile, the estimated risk reduction associated with additional accident mitigation instrumentation is judged to be negligible.	Considering uncertainty and potential impacts from external events does not introduce any significant changes. No change to the screening criteria category.	N/A
265	4.d. Passive Overpressure Relief	This SAMA will prevent catastrophic failure of the containment. Controlled relief through a selected vent path has a greater potential for reducing the release of radioactive material than through a random break.	#6 - Retain	This SAMA may be a cost effective means of reducing risk at Quad Cities. Quad Cities has installed a hard piped containment vent system that provides a controlled means of containment overpressure relief. The passive feature of adding a rupture disk to this system introduces competing risks that limit the usefulness of the vent over the spectrum of severe accidents.	Still retained.	13
271	Train operations crew for response to inadvertent actuation signals	This SAMA would improve chances of a successful response to the loss of two 120V AC buses, which may cause inadvertent signal generation.	#4 - No significant safety benefit	The 120V AC system is not risk significant at Quad Cities. While other plants have identified specific 120V AC failure scenarios that would lead the generation of inadvertent signals, no comparable vulnerabilities have been identified at Quad Cities.	Considering uncertainty and potential impacts from external events does not introduce any significant changes. No change to the screening criteria category.	N/A

Table 7-2
Revised Phase I SAMA Disposition (Assuming Maximum Averted Cost Risk of $500K)

Phase I SAMA ID number	SAMA title	Result of potential enhancement	Original / Revised Screening Criteria	Original Disposition	Revised Disposition Including Uncertainty and External Events	Phase II SAMA ID number
272	Install tornado protection on gas turbine generators	This SAMA would improve onsite AC power reliability.	#4 - No significant safety benefit	Additional measures could be taken to improve the protection of the on-site AC power sources; however, the IPEEE investigated risk from high wind events and found it to be negligible. Specifically, the emergency diesel generators are in safety category I structures.	Considering uncertainty and potential impacts from external events does not introduce any significant changes. No change to the screening criteria category.	N/A
277	Use RHRSW cross tie from opposite unit	This SAMA was identified as part of the risk insights from the Quad Cities PRA.	#4 - No significant safety benefit	The physical capability to establish the cross tie exists. There are system procedures to perform the alignment. The insight merely is to establish additional training and to specify when it can be used. This insight while considered useful for further investigation is a safety enhancement that results in a small unmeasurable risk reduction benefit.	The RHRSW cross tie from the opposite unit is credited in the internal events and fire portion of the PRA model. The HEP values are based on the procedural direction provided in QCOA-1000, QCOP-1000-15, QCOP-1000-20, and QCOP-1000-30.	N/A
278	Provide mechanical stops on AOVs for venting	This SAMA seeks to physically prevent rapid containment depressurization during venting by imposing physical stops on the vent valves.	#4 - No significant safety benefit	Calculation for BWR containment depressurization rates show that such physical stops are not adequate by themselves for this purpose.	Considering uncertainty and potential impacts from external events does not introduce any significant changes. No change to the screening criteria category.	N/A
279	Control containment venting within a narrow band of pressure	This SAMA was derived from the Quad Cities Risk Insights document to establish a narrow pressure control band that would thereby prevent rapid containment depressurization when venting is implemented thus avoiding adverse impacts on the low pressure ECCS injection systems taking suction from the torus.	#6 - Retain	There is a minor potential risk reduction associated with the SAMA and a cost associated with procedure changes, training, and documentation.	Still retained.	14

Response 7(c):

"[Provide] an assessment of the impact on the Phase 2 evaluation if risk reduction estimates are increased to account for uncertainties in the risk assessment and the additional benefits associated with external events (as applicable). Please consider the uncertainties due to both the averted cost-risk and the cost of implementation to determine changes in the net value for these SAMAs."

To perform this assessment, a two-step approach was taken. The first step was to reexamine the Phase II evaluation utilizing an upper bound maximum averted cost estimate of $500K consistent with the revised Phase I screening. This revised screening would then result in a set of potential plant changes that could be cost beneficial when compared to the upper bound estimate of the averted cost. For these potential enhancements, a comparison was then made to a more realistic estimated averted cost to determine if the proposed change would be cost beneficial.

To provide an upper bound estimate on the risk reduction estimates to account for potential uncertainties on the risk assessment and the additional benefits associated with external events, each of the previously retained Phase II SAMAs plus the additional retained SAMAs from the revised Phase I screening in Response 7(b) have been reassessed. The reassessment assumes that the maximum averted cost risk is about $500K compared to the original maximum averted cost of $111K used in the ER. Table 7-3 shows the results of this reassessment with each of the previously calculated averted costs multiplied by a factor of 5.

Additional Phase II SAMA Analyses

The revised Phase I screening described in Response 7(b) resulted in three additional SAMAs being carried forward to Phase 2. One of those SAMAs was judged to be adequately characterized by another SAMA investigation to estimate the potential cost benefit. However, two additional Phase II SAMA analyses were also performed to support the revised screening provided in Table 7-3. Each of these is described below.

PHASE II SAMA NUMBER 15

Description: Provide means for inter-unit crosstie for TBCCW

Model Changes: Set TBCCW initiating event frequency and all TBCCW component failures to 0.0.

Results: The results from this case indicate a decrease from the base CDF of 2.16E-6/yr to 2.05E-6/yr. The decrease in CDF (reduction of 1.1E-7/yr) applies primarily to loss of DHR and ATWS scenarios (Class II and IVA) due to the dependence of BOP systems on TBCCW. The main condenser and containment venting are DHR systems that are dependent on TBCCW. In addition, the main condenser and Feedwater systems support ATWS mitigation. There was no reduction in LERF (base LERF = 2.67E-7/yr). This would lead to an averted cost-risk of $5,714 utilizing the same methodology and assumptions that were utilized in the ER.

PHASE II SAMA NUMBER 16

Description: Enhance bypass of MSIV isolation interlock (ATWS)

Model Changes: Reduce HEP for operator failure to bypass MSIV low RPV level interlock (ATWS) from 0.91 to 1E-2. In addition, increase complementary HEP for operator successful bypass MSIV low RPV level interlock (ATWS) from 9E-2 to 0.99.

Results: The results from this case indicate a decrease from the base CDF of 2.16E-6/yr to 2.09E-6/yr. The decrease in CDF (reduction of 6.5E-8/yr) applies only to ATWS scenarios (Class IVA and IC). Maintaining the availability of the main condenser for decay heat removal enhances the ability for successful mitigation of ATWS events. The LERF decreased from the base LERF of 2.67E-7/yr to 2.64E-7/yr. This would lead to an averted cost-risk of $5,950 utilizing the same methodology and assumptions that were utilized in the ER.

PHASE II SAMA NUMBER 17

Description: Allow cross connection of uninterruptable compressed air supply to opposite unit. (or examine lower cost alternative of providing backup air bottles or portable compressors).

The largest benefit of this SAMA would be derived by making the containment vent system more reliable. Consequently, for the initial screening, it was judged that characterization by Phase II SAMA 13 (i.e., Passive Containment Overpressure Relief) that had previously considered the potential averted cost from eliminating all containment venting failures would be appropriate. This SAMA had been shown to result in an averted cost-risk of $7,217. This is the initial upper bound value that is also used for Phase II SAMA 17.

The results of the reassessment including the three new Phase II SAMA analyses are provided in Table 7-3. The potential costs are consistent with those provided in Response 12.

Table 7-3
Revised Phase II SAMA Disposition (Assuming Maximum Averted Cost Risk of $500K)

Phase II SAMA ID number	Phase I SAMA ID number	SAMA title	Result of potential enhancement	Upper Bound Averted Cost Estimate	Potential Cost	Revised Disposition
1	32	Provide means for alternate SSMP room cooling	The SSMP requires room cooling at extended times. This SAMA would allow SSMP operation late in accidents when normal room cooling has failed.	5 * $12,280 = $61,400 * 2 Units = $122,800	$50-100K for procedural enhancements with engineering analysis required.	Current capabilities exist to utilize FPS as a backup means of providing SSMP room cooling. Procedural direction for performing this action is provided in QCOP 2900-02. The HEP (BSSOPSSRMCLNGH--) for this action is currently 1.1E-1. Improvements to this HEP value by adding better procedural direction, or providing lower cost alternatives of adding procedures to open doors or to provide portable fans to extend SSMP run time could be cost beneficial. Retain for more detailed cost benefit analysis (see Table 7-4).
2	36	Develop an enhanced drywell spray system.	SAMA would provide a redundant source of water to the containment to control containment pressure, when used in conjunction with containment heat removal.	5 * $10,703 = $53,515 * 2 Units = $107,030	$50-100K for procedural enhancements with engineering analysis required.	The fire protection system (FPS) can already provide water to the RHR system at QCNPS, but procedures have not been developed to use it as a containment spray source. Assuring the viability of such a proposed change would also require engineering analysis. However, the total implementation costs could be less than the upper bound averted cost estimate. Retain for more detailed cost benefit analysis (see Table 7-4).
3	94	Use fuel cells instead of lead-acid batteries.	SAMA would extend DC power availability in an SBO.	5 * $4,662 = $23,310 * 2 Units = $46,620	>$100K for fuel cells, or $50-100K for lower cost alternative of providing a portable generator to the battery chargers and procedural implementation / training.	Not cost beneficial. Either replacing batteries with fuel cells or a lower cost alternative of implementing portable generators to prolong battery life would be more costly than the upper bound averted cost estimate.

Table 7-3
Revised Phase II SAMA Disposition (Assuming Maximum Averted Cost Risk of $500K)

Phase II SAMA ID number	Phase I SAMA ID number	SAMA title	Result of potential enhancement	Upper Bound Averted Cost Estimate	Potential Cost	Revised Disposition
4	96	Improve 4.16-kV bus cross-tie ability.	Enhance procedures to direct 4kV bus cross-tie. If this procedural step already exists, investigate installation of hardware that would perform an automatic cross-tie to the opposite 4kV bus given failure of the dedicated diesel.	5 * $758 = $3,790 * 2 Units = 7,580	$25-50K for procedural enhancements	Not cost beneficial. The upper bound averted cost estimate of $6.8K is far below the minimum procedural change estimate of $25K. Additionally, given the complications and concerns associated with cross-tieing buses, any related procedural change is probably more likely to be a higher cost procedure change than a lower cost procedure change.
5	108	Create a backup source for diesel cooling. (Not from existing system)	This SAMA would provide a redundant and diverse source of cooling for the diesel generators, which would contribute to enhanced diesel reliability.	5 * Negligible = Negligible	Not Required	Not cost beneficial. Also see Response 13(c). The SBO DGs already include a diverse source of diesel generator cooling compared to EDG 1, EDG 2, and EDG 1/2.
6	131	Provide procedures for (a) bypassing major DC buses; (b) locally starting equipment	This SAMA would allow for powering specific loads given a DC bus failure and/or the ability to start equipment locally that normally requires DC power for a control room start.	5 * $31,987 = $159,935 * 2 Units = $319,870	$50-100K for procedural enhancements with engineering analysis required, plus $100K minimum for hardware changes.	Preparing procedural direction to bypass major DC buses, providing instructions for local start, and providing backup hardware capabilities for this function may be cost beneficial when compared to the upper bound averted cost estimate. Retain for more detailed cost benefit analysis (see Table 7-4).
7	216	Delete High DW Pressure Signal from SDC isolation	This SAMA would allow the initiation of SDC when the drywell is at elevated pressures.	5 * $812 = $4,060 * 2 Units = $8,120	$25-50K for procedural enhancements	Not cost beneficial. The upper bound averted cost estimate is far below the minimum procedure change estimate of $25K.
8	219	Develop procedures to control Feedwater flow without 125 VDC power to prevent tripping Feedwater on High/Low level	This SAMA increases the functionality of Feedwater in loss of DC scenarios and increases the probability of successful level control.	5 * $16,694 = $83,470 * 2 Units = $166,940	$100-200K for procedural enhancements with engineering analysis, potential for testing, and training required.	Overall implementation costs would include developmental work and extensive training. However, this could be cost beneficial when compared to the upper bound averted cost estimate. Retain for more detailed cost benefit analysis (see Table 7-4).

Table 7-3
Revised Phase II SAMA Disposition (Assuming Maximum Averted Cost Risk of $500K)

Phase II SAMA ID number	Phase I SAMA ID number	SAMA title	Result of potential enhancement	Upper Bound Averted Cost Estimate	Potential Cost	Revised Disposition
9	220	Remove Loop Select Logic	In the event that there is no break in the recirc loops and there is a Loop "B" injection path failure, the Loop "A" injection path is precluded from use. Removal of the LPCI Loop Select Logic or installation of a bypass switch would allow use of the "A" loop for injection in the event of a "B" injection path failure.	5 * Negligible = Negligible	Not Required	Not cost beneficial. The benefit from this change is limited to LOCA scenarios.
10	221	Demonstrate RCIC operability following depressurization	This SAMA would increase the operators' options for low pressure vessel injection.	5 * $21,464 = $107,320 * 2 Units = $214,640	$100-200K for procedural enhancements with engineering analysis and training required.	Overall implementation costs would include developmental work and extensive training. However, this could be cost beneficial when compared to the upper bound averted cost estimate. Retain for more detailed cost benefit analysis (see Table 7-4).
11	242	Diversify the explosive valve operation	An alternate means of opening a pathway to the RPV for SBLC injection would improve the success probability for reactor shutdown.	5 * $2,584 = $12,920	>$100K / unit	Not cost beneficial. Any hardware change would easily exceed the upper bound averted cost estimate.
12	243	Enrich Boron	The increased boron concentration will reduce the time required to achieve the shutdown concentration. This will provide increased an increased margin in the accident timeline for successful operator activation of SBLC.	5 * $718 = $3,590	Not Required	Not cost beneficial. Minimal benefit is obtained and associated implementation costs would easily exceed the upper bound averted cost estimate.

Table 7-3
Revised Phase II SAMA Disposition (Assuming Maximum Averted Cost Risk of $500K)

Phase II SAMA ID number	Phase I SAMA ID number	SAMA title	Result of potential enhancement	Upper Bound Averted Cost Estimate	Potential Cost	Revised Disposition
13	265	4.d. Passive Overpressure Relief	This SAMA will prevent catastrophic failure of the containment. Controlled relief through a selected vent path has a greater potential for reducing the release of radioactive material than through a random break.	5 * $7,217 = $36,085	>$100K / unit	Not cost beneficial. Implementation of this SAMA would involve extensive hardware changes that would exceed the upper bound averted cost estimate.
14	279	Control containment venting within a narrow band of pressure	This SAMA was derived form the Quad Cities Risk Insights document to establish a narrow pressure control band that would thereby prevent rapid containment depressurization when venting is implemented thus avoiding adverse impacts on the low pressure ECCS injection systems taking suction from the torus.	5 * $23,550 = $117,750 * 2 Units = $235,500	$100-200K for procedural enhancements with engineering analysis and training required.	Current procedures allow considerable flexibility in implementing containment venting. Additionally, there is plenty of time for the Emergency Response Organization to develop a strategy to supplement the guidance in the current procedure. However, implementing, establishing a procedure, and providing training for the recommended approach may be cost beneficial when compared to the upper bound averted cost estimate. Retain for more detailed cost benefit analysis (see Table 7-4).
15 (1)	20	Enhance procedural guidance for use of cross-tied component cooling or service water pumps.	SAMA would reduce the frequency of the loss of component cooling water and service water.	5 * $5,714 (2) = $28,570 * 2 Units = $57,140	Alternative investigated to provide TBCCW cross-tie capabilities to other unit. $100K minimum for hardware change.	Not cost beneficial. Implementation of this SAMA would involve extensive hardware changes that would exceed the upper bound averted cost estimate.

Table 7-3
Revised Phase II SAMA Disposition (Assuming Maximum Averted Cost Risk of $500K)

Phase II SAMA ID number	Phase I SAMA ID number	SAMA title	Result of potential enhancement	Upper Bound Averted Cost Estimate	Potential Cost	Revised Disposition
16[(1)]	237	Bypass MSIV isolation in Turbine Trip ATWS scenarios	SAMA will afford operators more time to perform actions. The discharge of a substantial fraction of steam to the main condenser (i.e., as opposed to into the primary containment) affords the operator more time to perform actions (e.g., SLC injection, lower water level, depressurize RPV) than if the main condenser was unavailable, resulting in lower human error probabilities	5 * $5,950 [(2)] = $29,750 * 2 Units = $59,500	$50-100K for procedural enhancements with engineering analysis required, plus $100K minimum for hardware changes to implement automatic MSIV isolation bypass capabilities.	Not cost beneficial. Implementation of this SAMA would involve procedural and hardware changes that would exceed the upper bound averted cost estimate.
17[(1)]	225	Allow cross connection of uninterruptable compressed air supply to opposite unit.	SAMA would increase the ability to vent containment using the hardened vent.	5 * $7,217[(3)] = $36,085 * 2 Units = $72,170	Lower cost alternative of providing backup bottles or portable air compressors estimated at $50-100K for procedural enhancements, training, and hardware modifications.	Implementation of this SAMA would require procedural and hardware changes. However, this could be cost beneficial when compared to the upper bound averted cost estimate. Retain for more detailed cost benefit analysis (see Table 7-4).

Notes to Table 7-3

(1) This is a new Phase II SAMA identifier that was not included in the ER.

(2) Detailed development of the PRA model changes made for this Phase II SAMA investigation are provided prior to the table.

(3) This SAMA is initially conservatively estimated as providing the same benefit as Phase II SAMA 13 (with vent failure modes set to zero).

Response 7(c) - continued:

"[Provide] an assessment of the impact on the Phase 2 evaluation if risk reduction estimates are increased to account for uncertainties in the risk assessment and the additional benefits associated with external events (as applicable). Please consider the uncertainties due to both the averted cost-risk and the cost of implementation to determine changes in the net value for these SAMAs."

As can be seen in Table 7-3, seven of the Phase II SAMAs could be categorized as cost beneficial when compared to the upper bound averted cost estimate. It should be noted, however, that there are many factors to consider when looking at the benefits of the SAMA candidates. Plant specific implementation of SAMA candidates may be complicated by space limitations, outage costs, regulatory requirements, and other considerations. These factors tend to result in underestimation of the costs. Additionally, the specific PSA analyses that were performed in addressing specific SAMA candidates were done optimistically. That is, the potential cost-benefit was derived from a case that maximized the CDF reduction (and/or offsite release) that would result from implementation of the SAMA. Both of these factors would, in effect, offset the uncertainties associated with the CDF estimates.

A factor of 5 is judged to be appropriate to account for uncertainty and to account for potential contributions from external events and internal flooding that were not included in the averted cost estimates in the ER. Attachment A includes information about why a factor of three is more appropriate than a factor of more than 10 that would be obtained if the unmodified Fire PRA results were used directly.[3] The remaining portion (from a factor of 3 up to 5) is to account for uncertainty, internal flooding, and the potential contributions from other external events.

Additionally, each SAMA case was re-examined to ensure that the better estimated averted cost from the internal events model was appropriately representing the potential benefit rather than representing the maximum benefit as was typically done for screening purposes. This includes a re-examination of the assumptions utilized in the initial screening analysis as well as recognizing existing model limitations that could lead to over-estimation of the averted costs. In some cases, the implementation costs were also refined to better reflect the potential cost benefit. The results of this additional screening are illustrated in Table 7-4.

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[3] Attachment A provides an assessment of the use of quantitative risk estimates from Fire PRAs, and why it is judged that the calculated CDF values should not be directly compared at this time.

Table 7-4
Refined Phase II SAMA Disposition of Remaining Quad Cities SAMA Candidates

Phase II SAMA ID number	Phase I SAMA ID number	SAMA title	Result of potential enhancement	Better Estimated Averted Cost	Better Estimated Potential Cost	Better Estimate Disposition
1	32	Provide means for alternate SSMP room cooling	The SSMP requires room cooling at extended times. This SAMA would allow SSMP operation late in accidents when normal room cooling has failed.	5 * $12,280 / 5 for proper credit of existing procedures = $12,280 * 2 Units = $24,560	$50-100K for procedural enhancements with engineering analysis required.	Not cost beneficial. Current capabilities exist to utilize FPS as a backup means of providing SSMP room cooling. Procedural direction for performing this action is provided in QCOP 2900-02. The HEP (BSSOPSSRMCLNGH--) for this action is currently 1.1E-1 based on a lack of clear symptom-based direction for subsequent losses of service water following initial use of the SSMP. However, all of the dominant cutsets that include this HEP value result from a loss of service water initiated event for which case, the procedural direction to utilize FPS for SSMP room cooling is very clear. Based on a re-evaluation of the procedure, a significant reduction in the HEP value is anticipated (for the loss of service water initiated event) as part of the next PRA model update. This will greatly minimize the risk reduction worth associated with this HEP. No additional procedural change is required. Benefit from reducing the current HEP value to a more realistic value for the scenarios of interest is estimated to provide at least a reduction factor of five on the potential averted cost benefit. This precludes even low cost alternatives of providing procedures to open doors or to provide portable fans to extend SSMP run time as being cost beneficial.

Table 7-4
Refined Phase II SAMA Disposition of Remaining Quad Cities SAMA Candidates

Phase II SAMA ID number	Phase I SAMA ID number	SAMA title	Result of potential enhancement	Better Estimated Averted Cost	Better Estimated Potential Cost	Better Estimate Disposition
2	36	*Develop an enhanced* drywell spray system.	*SAMA would provide a* redundant source of water to the containment to control containment pressure, when used in conjunction with containment heat removal.	*5 * $3,685* = $18,425 * 2 Units = $36,850	$50-100K for procedural enhancements with engineering analysis required.	*Not cost beneficial. The fire protection system (FPS)* can already provide water to the RHR system at QCNPS, but procedures have not been developed to use it as a containment spray source. Assuring the viability of such a proposed change would also require engineering analysis. Additionally, a more *thorough investigation of the proposed modification* would not alter the release categorization in two scenarios that accounted for much of the calculated averted cost. These two scenarios are as follows: • Station blackout or loss of multiple DC bus scenarios where power would not be available to operate the DW spray valves independent of the source of water. • Accident Class IIIC scenarios with LPCI pumps available that conservatively did not credit use of the existing LPCI pumps for the drywell spray function (e.g., low pressure permissive failures that would disable the injection function, but would not disable the DW spray function for these pumps). A more realistic averted cost estimate can be obtained for this SAMA by excluding these cases as benefiting from the proposed modification. In that case, consistent with the ER, there is still no *reduction in the CDF, but the LERF decreases from* the base case value of 2.7E-7/yr to 2.3E-7/yr (instead of down to 1.9E-7/yr), and other release category changes occur as well. With these changes, the averted cost estimate drops from the originally calculated value of $10,703 to $3,685 *using the same methodology and assumptions that* were utilized in the ER. The overall implementation costs would be higher than the estimated averted cost.

Table 7-4
Refined Phase II SAMA Disposition of Remaining Quad Cities SAMA Candidates

Phase II SAMA ID number	Phase I SAMA ID number	SAMA title	Result of potential enhancement	Better Estimated Averted Cost	Better Estimated Potential Cost	Better Estimate Disposition
6	131	Provide procedures for (a) bypassing major DC buses; (b) locally starting equipment	This SAMA would allow for powering specific loads given a DC bus failure and/or the ability to start equipment locally that normally requires DC power for a control room start.	5 * $31,987 = $159,935 per unit	$200K per unit for procedural enhancements with extensive engineering analysis, and extensive training required. A series of $100K minimum hardware changes could also be required.	Not cost beneficial. The initial averted cost estimate conservatively assumed that changes could be made to several systems so that DC power failures would not fail the systems. This is unrealistic. The first idea is to "bypass major DC buses." A small number of DC distribution buses at QC can be fed from either Unit 1 or Unit 2 DC. Those alternative feeds are already proceduralized in the loss of DC procedures. With other DC buses, there is no way to "bypass" DC buses or provide alternative feeds. *Therefore, doing so at the DC bus level would* involve adding hardware–buses, distribution cabinets, and breakers–to make the connections. This would be in addition to designs and preparation of procedures to use them. Alternatively, provide temporary cables to feed DC from a nearby switchgear of the other division to the switchgear which has key equipment and whose DC division is unavailable. The hardware cost may be less than new buses or new distribution cabinets, but it's still expensive because one has to plan in advance where to obtain the alternative DC for each key load and how to connect it without adversely impacting the one operable DC division that is available.

Table 7-4
Refined Phase II SAMA Disposition of Remaining Quad Cities SAMA Candidates

Phase II SAMA ID number	Phase I SAMA ID number	SAMA title	Result of potential enhancement	Better Estimated Averted Cost	Better Estimated Potential Cost	Better Estimate Disposition
6 (cont'd)	131	Provide procedures for (a) bypassing major DC buses; (b) locally starting equipment	This SAMA would allow for powering specific loads given a DC bus failure and/or the ability to start equipment locally that normally requires DC power for a control room start.	5 * $31,987 = $159,935 per unit	$200K per unit for procedural enhancements with extensive engineering analysis, and extensive training required. A series of $100K minimum hardware changes could also be required.	The second idea is to "locally start equipment." Locally starting equipment without DC power is not a trivial action. The DC normally provides not only control signals for breaker operation to start and stop equipment, but it also provides protection and interlocks. 4 kV and 480V AC breakers can be manually closed locally, but doing so is a personnel hazard if a fault exists and there is no protection. Also, without DC, one must be aware of designed interlocks to ensure that they are all satisfied before one took the bold step of locally closing the breaker. For example, oil lift pumps may need to be started or suction valves may need to be ensured open, since the normal interlocks would not be available without DC. That is why one would need to study each individual piece of equipment of interest, one-by-one, to know what precautions would be needed before locally closing a breaker. Preparing procedural direction to bypass major DC buses, providing instructions for local start, and providing training for the recommended approaches would lead to overall implementation costs that would easily exceed the upper bound of the estimated potential cost, or $200K per unit. This would lead to potential costs that are higher than the estimated averted cost.

Table 7-4
Refined Phase II SAMA Disposition of Remaining Quad Cities SAMA Candidates

Phase II SAMA ID number	Phase I SAMA ID number	SAMA title	Result of potential enhancement	Better Estimated Averted Cost	Better Estimated Potential Cost	Better Estimate Disposition
8	219	Develop procedures to control Feedwater flow without 125 VDC power to prevent tripping Feedwater on High/Low level	This SAMA increases the functionality of Feedwater in loss of DC scenarios and increases the probability of successful level control.	5 * $16,694 = $83,470 * 2 Units = $166,940	$200K for procedural enhancements with engineering analysis, potential for testing, and extensive training required.	Not cost beneficial. The difficulty of controlling Feedwater without DC power at Quad Cities is not with the Feedwater control system but, rather, with the leakage past the closed Feedwater regulation valves. Since it is not feasible to get such throttling valves to seal tightly, and since compensating actions are difficult with a loss of DC, writing such procedures would require significant development work and engineering analysis. Testing and experimentation might also be required. Costs would include developmental work and extensive training. This would lead to overall implementation costs closer to the upper bound of the estimated potential cost, or $200K. This would lead to potential costs that are higher than the estimated averted cost.

Table 7-4
Refined Phase II SAMA Disposition of Remaining Quad Cities SAMA Candidates

Phase II SAMA ID number	Phase I SAMA ID number	SAMA title	Result of potential enhancement	Better Estimated Averted Cost	Better Estimated Potential Cost	Better Estimate Disposition
10	221	Demonstrate RCIC operability following depressurization	This SAMA would increase the operators' options for low pressure vessel injection.	5 * $21,464 / 3 with some credit for existing procedures and capabilities = $35,773 * 2 Units = $71,546	$200K for procedural enhancements with engineering analysis and extensive training required.	Not cost beneficial. All of the averted cost for this SAMA comes from loss of containment heat removal scenarios with successful venting and subsequent loss of low pressure ECCS. Currently, only CRD and SSMP are credited for long term injection in the applicable scenarios. This is the same scenario examined in Phase II SAMA 14. Current procedures allow considerable flexibility in implementing containment venting and providing long term injection, and there is plenty of time for the Emergency Response Organization (ERO) to develop a strategy to supplement the guidance in the current procedure. The QC EOPs clearly note that NPSH/Vortex limits are a concern and note that the CST is preferred if using SSMP, HPCI, or RCIC. The EOPs also mention specific procedures for bypassing HPCI or RCIC trip setpoints to prolong injection from these systems if necessary. Additionally, a long list of alternate injection systems is provided that could provide a separate source of RPV injection following venting [the most notable of these is LPCI from the CST (QCOP 1000-02), Condensate from the hotwell with makeup provided by Standby Coolant Supply (QCOP 3200-09), or the use of the fire system through RHR (QCOP 4100-11)]. Given all of these considerations, it is estimated that the averted cost estimate is high by at least a factor of three for these scenarios compared to the capabilities that already exist and could be credited based on existing procedures. The revised best estimate averted cost includes this reduction factor. Performing engineering analysis to support the viability of such an approach, establishing a change to the EOPs, and providing training for the recommended approach would lead to overall implementation costs closer to the upper bound of the estimated potential cost, or $200K. This would lead to potential costs that are higher than the estimated averted cost.

Table 7-4
Refined Phase II SAMA Disposition of Remaining Quad Cities SAMA Candidates

Phase II SAMA ID number	Phase I SAMA ID number	SAMA title	Result of potential enhancement	Better Estimated Averted Cost	Better Estimated Potential Cost	Better Estimate Disposition
14	279	Control containment venting within a narrow band of pressure	This SAMA was derived form the Quad Cities Risk Insights document to establish a narrow pressure control band that would thereby prevent rapid containment depressurization when venting is implemented thus avoiding adverse impacts on the low pressure ECCS injection systems taking suction from the torus.	5 * $23,550 / 3 with some credit for existing procedures and capabilities = $39,250 * 2 Units = $78,500	$200K for procedural enhancements with engineering analysis and extensive training required.	Not cost beneficial. All of the averted cost for this SAMA comes from loss of containment heat removal scenarios with successful venting and subsequent loss of low pressure ECCS. Currently, only CRD and SSMP are credited for long term injection in the applicable scenarios. This is the same scenario examined in Phase II SAMA 10. Current procedures allow considerable flexibility in implementing containment venting and providing long term injection, and there is plenty of time for the Emergency Response Organization (ERO) to develop a strategy to supplement the guidance in the current procedure. The QC EOPs clearly note that NPSH/Vortex limits are a concern and note that the CST is preferred if using SSMP, HPCI, or RCIC. The EOPs also mention specific procedures for bypassing HPCI or RCIC trip setpoints to prolong injection from these systems if necessary. Additionally, a long list of alternate injection systems is provided that could provide a separate source of RPV injection following venting [the most notable of these is LPCI from the CST (QCOP 1000-02), Condensate from the hotwell with makeup provided by Standby Coolant Supply (QCOP 3200-09), or the use of the fire system through RHR (QCOP 4100-11)]. Given all of these considerations, it is estimated that the averted cost estimate is high by at least a factor of three for these scenarios compared to the capabilities that already exist and could be credited based on existing procedures. The revised best estimate averted cost includes this reduction factor. Implementing, establishing a procedure, and providing training for the recommended approach would lead to potential costs closer to the upper bound of the estimated potential cost, or $200K. This would lead to overall implementation costs that are higher than the estimated averted cost.

Table 7-4
Refined Phase II SAMA Disposition of Remaining Quad Cities SAMA Candidates

Phase II SAMA ID number	Phase I SAMA ID number	SAMA title	Result of potential enhancement	Better Estimated Averted Cost	Better Estimated Potential Cost	Better Estimate Disposition
17	225	Allow cross connection of uninterruptable compressed air supply to opposite unit.	SAMA would increase the ability to vent containment using the hardened vent.	5 * $2,796 = $13,980 * 2 Units = $27,960	Lower cost alternative of providing backup bottles or portable air compressors estimated at $50-100K for procedural enhancements, training, and hardware modifications.	Not cost beneficial. Revised best estimate averted cost calculated from setting instrument air recovery to zero instead of determining potential averted cost from a perfect vent scenario. The results from this case indicate a reduction of 5.6E-8/yr in CDF (compared to the upper bound reduction of 1.5E-7/yr utilized in Table 7-3) that applies to loss of DHR scenarios (Class II). There was no reduction in LERF. With these changes, the averted cost estimate drops from the originally calculated value of $7,217 to $2,796 using the same methodology and assumptions that were utilized in the ER. The overall implementation costs are estimated to be higher than the estimated averted cost.

RAI 8

For certain SAMAs considered in the ER, there may be lower cost alternatives that could achieve much of the risk reduction. As one example, Phase 2 SAMA #3 evaluated the use of fuel cells instead of lead-acid batteries, but lower cost alternatives, such as adding a diesel-driven battery charger, were not explored. Please confirm that low cost alternatives to Phase 2 SAMAs were considered, and provide a brief discussion of these alternatives.

Response 8

Lower cost alternatives were considered in both the initial Phase I screening all the way through to the final revised Phase II screening. Examples included a portable generator to provide prolonged battery capacity (see Table 7-3, Phase II SAMA 3), and backup bottles or portable compressors for supplementing instrument air capabilities (see Table 7-3, Phase II SAMA 17). Several additional lower cost alternatives were also explored in the form of potential procedural changes (see Table 7-3, Phase II SAMAs 1, 2, 4, 6, 7, 8, 10, and 14). While many of these may only involve procedural changes in concept, a more thorough investigation leads to the finding that more costs would actually be incurred when considering that the procedure changes may also require engineering analysis, potential experimentation, and extensive training (see also Response 12). Additionally, a more refined evaluation of the initial averted cost estimates indicate, that in most of the cases, analysis simplifications or existing model limitations tend towards an overestimation of the averted cost. The identified modeling limitations are not considered significant when considering the typical uses of the PRA models, but come to the forefront when specific risk reduction values are calculated. As such, none of the remaining SAMAs (including lower cost alternatives) were determined to be cost beneficial.

RAI 9

During the review of the EPU application, the staff noted several areas where the PSA should be modified to reflect modifications to the plant or changes in success paths. These include: a plant modification to install a recirculation pump runback control circuit; a plant modification to trip the condensate/booster pump D in the event of a LOCA to prevent an overload condition from occurring; a change in success criteria for reactor pressure vessel (RPV) depressurization in a transient without a stuck open relief valve (two valves under EPU conditions); a change in success criteria for RPV overpressure protection in ATWS sequences (12 of 13 valves under EPU conditions). Confirm if these model changes, as well as others, have been incorporated in the PSA used for the SAMA analysis. For those not incorporated, provide an assessment of the impact that the model change would have on the SAMA analysis.

Response 9

The model was revised to include all appropriate EPU changes:

- The purpose of the recirc. pump runback control circuit is to prevent the reactor trip frequency from increasing due to EPU. The recirc. pump runback is needed because there no longer are "spare" condensate pumps or feedwater pumps. Due to this modification, the transient initiating event frequency is not expected to change. However, effects on the plant can only be incorporated in the PRA after some plant experience via the next periodic update of initiating event frequencies.
- The potential risk impact of the recirc. runback modification was addressed in a response to a NRC RAI to support the EPU application [Reference 9-1]. The response to the RAI addressed both 1) the failure of the recirc. runback to operate as designed, and 2) spurious recirc. runback. The RAI judged that the incorporation of the recirc. runback modification would result in a negligible risk increase.

  The circuit to trip condensate/condensate booster pump "D" on a LOCA signal is expected to be very reliable. The risk impact of the condensate/condensate booster pump "D" trip logic was also addressed in Reference 9-1. The risk impact was calculated to be 1.7E-10/yr. Due to the minor contribution to CDF, this failure mode was not explicitly included in the PRA model.
- The success criterion for RPV depressurization is reflected in the revised transient without SORV model.
- The success criterion for ATWS overpressure protection is reflected in the revised ATWS model.
- The higher decay heat load due to power uprate reduces the time available for certain operator actions. This has been reflected in revised HEP's for those actions.

REFERENCE

[9-1] Letter from K.A. Ainger, Exelon Generation Company, to U.S. NRC, "Additional Risk Information Supporting the License Amendment Request to Permit Uprated Power Operation at Dresden Nuclear Power Station and Quad Cities Nuclear Power Station", RS-01-168, August 14, 2001.

RAI 10

During the review of the EPU application, the staff noted that there is potentially a new means of inducing a LOOP initiating event under EPU conditions. The end result could be an overduty condition on the unit auxiliary or reserve auxiliary transformer. Given this new condition, please provide an evaluation of the costs and benefits associated with the replacement of the affected transformer with a higher capacity transformer.

Response 10

The risk impact of the induced LOOP initiating event was addressed in a response to a NRC RAI to support the EPU application [Reference 10-1]. Information from the response to the RAI is summarized below.

BACKGROUND

During normal operation the station loads are distributed between the Unit Auxiliary Transformer (UAT) and the Reserve Auxiliary Transformer (RAT). Normally, the loads for two non-essential 4kV buses are aligned to the UAT and the loads for the other two non-essential 4kV buses are aligned to the RAT. If either the UAT or RAT become unavailable during normal operation without a reactor scram, the increased loads for the EPU configuration may result in an overload condition for the remaining transformer's bus duct connection to the 4kV buses.

The scenario of concern is a loss of the UAT or RAT due to transformer failure, failure of protective relaying (e.g., false fast transfer signal), or spurious opening of multiple circuit breakers [see note (1)], causing a fast transfer of all running loads to the other transformer. Under these conditions, certain bus duct segments are overloaded, requiring operator action within one hour to reduce load to within the bus duct rating. This action will be procedurally directed. The one hour time frame for load reduction was determined based on an Exelon Generation Company (EGC), LLC evaluation of a General Electric Company study on short term overload conditions for the bus ducts. The simplifying assumption is made that failure to take this action would lead to a loss of offsite power (LOOP). In reality, overload of the bus duct results in heating above the allowable temperature limits if ambient temperature is at the design value. No deterministic evaluation has been conducted to determine if overheating will result in complete failure of the bus duct, thereby causing a LOOP.

RESULTS

The induced LOOP initiating event is calculated to result in a 6E-9/yr increase in the Quad Cities Level 1 CDF. The risk evaluation accounts for the estimated frequency of the transformer overduty condition and failure of the plant or operating staff to mitigate the event.

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(1) Spurious opening of an individual circuit breaker to an individual 4kV bus would cause a fast transfer of the individual 4kV bus loads to the alternate transformer. However, based on the estimated EPU loads, the transfer of loads for a single 4kV bus (i.e., loads from three 4kV buses on a single transformer) would not place the transformer bus ducts in an overload condition.

CONCLUSIONS FOR SAMA

Based on the minor risk impact, the costs associated with the replacement of the affected transformer or associated electrical equipment (e.g., 4kV bus duct connections) is judged not to be warranted.

Additional details of the risk calculation can be found in Reference [10-1].

REFERENCE

[10-1] Letter from T. W. Simpkin (Exelon Generation Company) to U. S. NRC, "Additional Information Supporting the License Amendment Request to Permit Uprated Power Operation, Dresden Nuclear Power Station and Quad Cities Nuclear Power Station," RS-01-200, dated September 19, 2000.

RAI 11

In the original IPE (1993), the CDF was dominated by a dual-unit LOOP (contributing 56% to the internal events CDF). The Fussell-Vesely importance measure indicated that the most significant hardware contributors toward total CDF are the failures of the diesel generators (DGs), and the quantitative importance of emergency AC power sources is influenced significantly by the dependency of the plant on electrically-driven systems for long-term decay heat removal. In the modified IPE submittal (August 1996), the contribution for dual-unit LOOP remained unchanged. In the updated IPE (December 1996), the contribution to CDF has dropped to 33% (after two station blackout (SBO) DGs were added), however, the contribution to CDF remains significant. SAMAs that involve adding a DG, adding batteries, and the like were evaluated by QCNPS but eliminated on the basis that the plant already has five DGs, spare batteries, and the other SAMAs are too costly. Other than these improvements, please describe what measures or evaluations have been performed at QCNPS to reduce the risk from single- and dual-unit LOOP. Include a discussion of how the new SBO DGs are modeled in the current PSA including key assumptions.

Response 11

The CDF in the 2002B Quad Cities PRA Update is the same as the 1996 Updated IPE. This agreement in the total value is coincidental, given the number of model changes that have occurred since the Updated IPE. However, the dual-unit LOOP contribution is now 17% of the CDF instead of 33%. The single-unit LOOP contribution is now 2% instead of 22%. The combined contribution is now 19% instead of 55%.

The update that followed the 1996 Updated IPE, the 1999 Upgrade, was a major change, and it involved a conversion to the single-top fault tree methodology from the support state methodology previously used. Because of this, it is difficult to compare the model results directly. However, the changes that most likely contributed to the reduction in importance of offsite power are the following:

- The single-top fault tree better represents dependencies on support systems. For example, common-cause failure modes between diesel-generators in the support-state model required complicated conditional probability calculations between dependent event tree nodes. Within the single-top fault tree, dependencies are modeled explicitly using a linked fault tree approach. The dependencies of frontline equipment on support systems are more clear and precise. In addition, although credit for SBO diesel-generators was included in the Updated IPE, the single-top fault tree better represents the multitude of possible alignments of those diesels, as well as the multitude of bus alignments between units possible at Quad Cities.
- The diesel-generator mission time was reduced from 24 hours to 6 hours, consistent with the method for Peach Bottom in NUREG-4550.
- Data for loss of offsite power, loss of offsite power recovery, and plant equipment reliability and availability were updated in 1999 and, again, in 2002. Industry loss of offsite power performance has improved. And the plant-specific experience with diesel-generators, with breakers, and with turbine-driven pumps has significantly improved.
- EGC revised the common-cause factors based on NUREG/CR-5497 and NUREG/CR-5485.

- EGC completely revised the Human Reliability Analysis, using industry standard methods, the latest plant procedures, operator interviews, and simulator observations.

The response to RAI #1(d) notes that one change for the 2002B model is "Revised LOOP/DLOOP analysis for initiating event frequencies and non-recovery probabilities based upon a Midwest regional data filtering approach." This approach to developing loss of offsite power frequency and offsite power recover probability is based on analyzing published EPRI loss of offsite power data for applicability to Quad Cities. The Quad Cities PRA has a single-unit loss of offsite power initiator (LOOP), and a dual-unit loss of offsite power initiator (DLOOP). In different PRA's, different techniques have been used to estimate these frequencies.

For the 1999 model, EGC concluded that, since every nuclear station has two independent sources of offsite power, both single-unit stations and dual-unit stations can have DLOOP-like events and LOOP-like events. By sorting all industry loss of offsite power events in this way, one can develop generic LOOP and DLOOP frequencies, as well as developing a DLOOP non-recovery probability curve. This was done for the 1999 Quad update, using EPRI TR-106306,"Losses of Off-Site Power at U.S. Nuclear Power Plants—Through 1995." But, certain industry events, such as hurricanes and salt spray, have very long recovery times and simply cannot occur at Illinois nuclear sites. So, in the interest of realism, for the 1999 update, those hurricane and salt spray events were deleted before calculating the frequencies and recoveries.

For the 2002B model, a similar approach was followed, using the combined events from EPRI TR-1000158 (July 2000) and EPRI TR-106306 (April 1996) However, instead of simply deleting hurricane and salt spray events, EGC removed all loss of offsite power events and all unit-year experience for sites subject to hurricanes and salt spray. In addition, EGC eliminated all offsite power loss experience and unit-year data for sites that have exceptionally mild weather.

The resulting initiating event frequencies and non-recovery probability are shown in the table, below:

Model	DLOOP Frequency	LOOP Frequency	Non-recovery @ 4 hr.
1999 Update	1.87E-02/yr.	1.75E-02/yr.	0.16
Revision 2002B	1.20E-02/yr.	1.35E-02/yr.	0.22

The combined effect of all of these changes has resulted in considerably reduced importance of loss of offsite power. In addition, it appears that the updated IPE, while giving credit for the SBODGs, perhaps did not give sufficient credit.

Each unit SBODG can be aligned to either electrical division of either unit. In fact, since it is larger than an EDG, one SBODG can handle the shutdown loads of both units. This flexibility and operator actions based on the very detailed operating procedures for the SBODGs are reflected in the 1999 and 2002 models. While the SBODGs are of the same manufacture as the EDGs, they are of larger size, are tandem machines, and have updated control systems. The 1999 and 2002 models include common-cause failure of all five diesel-generators, but the factor used is smaller than if the five diesel-generators had been identical.

RAI 12

In Section 4.20.5 of the ER, Exelon states that a preliminary cost estimate was prepared for each of the remaining candidates (surviving the initial screening). In Section 4.20.6, it is stated that a more detailed implementation cost assessment is made only if the benefit is close to the estimated implementation cost. However, no implementation costs were provided for any of the Phase 2 SAMAs. Please provide the estimated implementation costs (preliminary cost estimates) for the 14 Phase 2 SAMAs, so that the staff can readily determine if any of these SAMAs are potentially cost-beneficial when considering the impact of external events and uncertainties. In addition, indicate what minimal costs were assumed for procedure changes, and what minimal costs were assumed for hardware changes.

Response 12

For all of the Phase 2 SAMAs evaluated in Section 4.20.5 of the ER, none of them had a benefit that was close to the potential implementation cost. Therefore, no detailed costs were required. As a supplement to the original SAMA evaluation, EGC has developed the following estimated implementation costs for use in Response 7(c). These costs have been estimated based on existing SAMA evaluations and have addressed the following cost elements:

- Procedural changes
- Engineering evaluations
- Hardware modifications
- Testing to support engineering evaluations and/or training to support procedural modifications

The following references have been used to assign an appropriate cost to these elements.

REFERENCES

[12-1] NUREG-1437, "Generic Environmental Impact Statement for License Renewal of Nuclear Plants, Oconee Nuclear Station", Supplement 2, U.S. Nuclear Regulatory Commission, Washington, D.C., December 1999.

[12-2] Peach Bottom SAMA Evaluation and RAI Responses

[12-3] HB Robinson SAMA Evaluation and RAI Response

[12-4] VC Summer SAMA Evaluation and RAI Response

[12-5] GE Nuclear Energy, "Technical Support Document for the ABWR," 25A5680, Rev. 1, November 1994.

PROCEDURAL CHANGES

Procedure development and modification requires preparation by a System Engineer, technical review and validation, oversight review, and a variety of additional plant reviews prior to release. In addition, plant staff will need to be trained prior to implementation. A few examples of other procedure change estimates are provided below.

- ABWR [12-5] indicates that improvements to existing maintenance procedures would cost approximately $300K.

- PB [12-2] describes a procedural modification to allow for cross-tie of CCW at an estimated implementation cost of $50K.

For the Quad Cities SAMA analyses, a range for procedural changes is estimated to cost from $25K to $50K. The lower estimate is judged to be more appropriate for changes to existing procedures, and the upper estimate is judged to be more appropriate for the development of new procedures.

ENGINEERING EVALUATIONS

In support of procedural and hardware modifications, an engineering evaluation will be required. For a procedural modification, the engineering requirements could easily double the cost of the change. This would increase the procedural change cost to an estimated range of $50K to $100K.

HARDWARE MODIFICATIONS

The following provides examples from previous SAMA evaluations.

- PB [12-2] evaluated alternate methods to provide cooling to the RHR pumps at an estimated implementation cost of $250K.

- PB [12-2] also estimated a cost of $1600K to replace all 8 station batteries.

- Numerous hardware changes were evaluated for the ABWR [12-5] at a cost range from $1000K to $6000K.

- Hardware modifications were evaluated for Oconee [12-1] including automatic refill systems for the refueling water storage tank, automatic switchover of HPI to the spent fuel pool, and others ranging from $1000K to $5000K.

For the Quad Cities SAMA analysis, several hardware modifications have been evaluated and range in cost from $100K to over $1000K. A minimum of $100K is used to account for engineering analysis, purchase, and maintenance of any proposed hardware modification.

TESTING/TRAINING

Similar to engineering costs to support a procedural change, testing of a plant system to establish operating limits or extensive training requirements to implement the procedure modification is estimated to double the cost of the procedural change. An example of this would be for a proposed SAMA to justify the operation of RCIC at low RPV pressures, or to implement a containment venting strategy within prescribed limits. Procedural changes in addition to potential testing/training costs could increase the overall implementation cost to a range of $100K to $200K.

SUMMARY OF IMPLEMENTATION COST

Based on a review of previous SAMA evaluations and an evaluation of expected implementation costs at Quad Cities, Table 12-1 provides the estimated costs for each potential element of the proposed SAMA implementation. Depending on the individual elements involved with each proposed SAMA, these estimates are then used to determine the total implementation cost with the remaining Phase II SAMAs as described in Response 7(c).

Table 12-1
Estimated Implementation Costs

Type of Change	Estimated Cost Range
Procedural only	$25K-$50K
Procedural change with engineering required	$50K-$100K
Procedural change with engineering and testing/training required	$100K-$200K
Hardware modification	$100K to > $1000K

RAI 13

For the Phase 2 SAMAs, the following information is needed to better understand the modification and/or the modeling assumptions:

a. *Phase 2 SAMA 1: The benefit of this SAMA is said to be a decrease in the CDF which applies primarily to loss of decay heat removal and late SBO scenarios. One of the proposed improvements is a procedure for opening the safe shutdown makeup pump (SSMP) doors and using portable fans for SSMP room cooling. It is unclear how this improvement would work under SBO conditions. Please clarify if this improvement is only meant to work for loss of decay heat removal scenarios, and how it might work under SBO conditions.*

b. *In the IPE, one of the unique features identified at QCNPS is the ability to cross-tie between units in emergency buses 14-1 and 24-1. Phase 2 SAMA 4 evaluates the development of procedures to allow the following cross-ties to be performed:*

   Bus 14-1 to Bus 24-1 from EDG 1
   Bus 24-1 to Bus 14-1 from EDG 2
   EDG 1 / 2 to Buses 13-1 and 23-1

   Explain why procedures have not already been developed for a cross-tie (Bus 14-1 to 24-1) that has been acknowledged in the IPE. Clarify whether this capability currently exists and is credited in the current PSA. If it is credited, please provide the key assumptions regarding this action (e.g., timing and operator non-procedural capability/knowledge) and the human error rate and its basis.

c. *Phase 2 SAMA 5: The following statement is made in Section 4.20.6.5 of the ER, "An additional EDG cooling source may be cost beneficial for Quad Cities." However, the analysis indicates that there is no benefit (averted risk). Explain why there is no benefit, and also explain why it was believed that such an improvement would be cost beneficial when there is no benefit.*

d. *For several Phase 2 SAMAs (6, 10, and 14), it appears that a majority of the effort would be in writing/revising procedures and training, and engineering work. Given the additional benefit of these SAMAs in external events and the impact of uncertainties, the benefit of these SAMAs could be substantially higher than assumed in the ER. Explain why these SAMAs would not be cost beneficial when the benefits associated with external events, and the impact of uncertainties are considered.*

Response 13(a):

"Phase 2 SAMA 1: The benefit of this SAMA is said to be a decrease in the CDF which applies primarily to loss of decay heat removal and late SBO scenarios. One of the proposed improvements is a procedure for opening the safe shutdown makeup pump (SSMP) doors and using portable fans for SSMP room cooling. It is unclear how this improvement would work

under SBO conditions. Please clarify if this improvement is only meant to work for loss of decay heat removal scenarios, and how it might work under SBO conditions."

Approximately 95% of the potential benefit of this SAMA was determined to be from Class II loss of containment heat removal scenarios and 5% was determined to be from Class IBL scenarios. The Class IBL late SBO characterization is based on the dominant cutsets for that sequence that do indeed include SBO-like conditions. However, the cutsets that are removed from that same sequence (that lead to about 5% of the noted CDF reduction) are actually better characterized as Class II scenarios as well since they don't involve an actual SBO condition, just a LOOP initiated event with other combinations of system failures. Removing the SSMP room cooling dependency decreases the Class II frequency because the primary cooling source for the SSMP is from Service Water. (The existing backup SSMP room cooling source is from Fire Protection.) Removing the room cooling dependency reduces many of the Loss of SW cutsets that lead to the Class II or Class IBL loss of decay heat removal sequences.

The proposed procedure for opening the SSMP room doors and using portable fans or SSMP room cooling was provided as an example potential option for removing the dependency. The benefit of this proposed enhancement would only occur in loss of decay heat removal scenarios, and would not be beneficial in true SBO scenarios since SSMP would also be unavailable. As described above, the benefit derived in the Phase II analysis is actually limited to loss of decay heat removal scenarios (some of which could occur from a LOOP/DLOOP initiated event with other combinations of system failures).

Response 13(b):

"In the IPE, one of the unique features identified at QCNPS is the ability to cross-tie between units in emergency buses 14-1 and 24-1. Phase 2 SAMA 4 evaluates the development of procedures to allow the following cross-ties to be performed:

Bus 14-1 to Bus 24-1 from EDG 1
Bus 24-1 to Bus 14-1 from EDG 2
EDG 1 / 2 to Buses 13-1 and 23-1

Explain why procedures have not already been developed for a cross-tie (Bus 14-1 to 24-1) that has been acknowledged in the IPE. Clarify whether this capability currently exists and is credited in the current PSA. If it is credited, please provide the key assumptions regarding this action (e.g., timing and operator non-procedural capability/knowledge) and the human error rate and its basis."

Cross-tie of Bus 14-1 to Bus 24-1, and cross-tie of Bus 13-1 to Bus 23-1, are already clearly proceduralized, but the cross-tie is not allowed to be used when the source of power to the live bus is that bus's emergency diesel-generator. The cross-tie can be used if the supplying bus is fed from its reserve aux transformer. The cross-tie also can be used if the supplying bus is fed from its unit SBO diesel-generator. The cross-tie is not currently allowed by procedure when the supplying bus is fed from its emergency diesel-generator. The reason for this is that an emergency diesel generator is not sized for all of the safe shutdown loads of two units. The SAMA consists of revising the procedures to permit one emergency diesel-generator to feed the buses of two units. Such revised procedures would necessarily require the operator to pay careful attention to the equipment running on both units to ensure that the emergency diesel generator was not overloaded. However, strategies could be implemented, such as alternating which unit is running suppression pool cooling, to ensure no EDG overload.

The intent of the SAMA investigation was to determine if improved reliability of existing cross-tie actions and/or expanded cross-tie capabilities would be cost beneficial. The Phase II SAMA analysis looked at improvements to three specific HEP values utilized in the PRA model to estimate the potential benefit for this SAMA. Two of the HEP values are based on existing cross-tie procedures, and the third event is based on non-procedural capability. Each of these HEPs are described below.

1. The action to align EDG 2 to the Unit 1 buses (or EDG 1 to the Unit 2 buses) is currently not proceduralized. It is included in the model with a relatively high failure rate of 0.9 based on engineering judgment. A reduction to the value of this HEP event (BACOP-U1U2EDGH--) to 9E-3 was made as part of the Phase II SAMA analysis. Because of the way the fault tree is built, one also needs to reduce the value of the HEP for cross-tying Bus 14-1 to 24-1 under other conditions. This action is dictated by Quad procedures (QCOA 6100-03 and QCOA 6100-04), and is represented by the HEP event BACOPXTIEBUS-H-- in the PRA model. With an estimated time to perform the action of 10 minutes and an available time window of 40 minutes based on the limiting case of an SBO with early HPCI and RCIC failures,a HEP value of 1.1E-2 was derived, based on EPRI's cause based methodology supplemented with ASEP estimates for short time frame events such as this one, and using THERP for the execution error. The Phase II SAMA analysis included a reduction in the HEP value for this event from its base PRA value of 1.1E-2 to 1.1E-4.

2. A specific event for simultaneously feeding Bus 13-1 and Bus 13-2 from EDG ½ is not included in the model. The benefit of this SAMA is modeled by reducing the failure probabilities of two human error events. Current procedures exist for aligning the swing diesel (i.e., EDG 1/2) to Unit 1 or Unit 2, as applicable. This action is dictated by Quad procedure QCOA 6100-03, and is represented in the PRA model by HEP event BDGOPDG1/2ALGH--. The HEP value of 5.5E-4 was derived based on EPRI's cause based methodology supplemented with ASEP estimates for short time frame events such as this one. The estimated time to perform the action is 10 minutes (JPM LP-003-I) with 40 minutes used as the available time window for the limiting case of an SBO with early HPCI and RCIC failures. The Phase II SAMA analysis included a reduction in the HEP value for this event from its base PRA value of 5.5E-4 to 5.5E-6. In addition, analogous to the case for Bus 14-1, one also needs to reduce the value of the HEP for cross-tying Bus 13-1 to 23-1. This action is represented for Bus 13-1 by the same HEP event, BACOPXTIEBUS-H--, as for Bus 14-1.

A factor of 100 reduction was made on three HEP values in the Phase II SAMA analysis to determine if improved reliability of existing cross-tie actions and/or expanded cross-tie capabilities would be cost beneficial. The averted cost risk of less than $1K indicated that such changes would not be cost beneficial.

Response 13(c):

"Phase 2 SAMA 5: The following statement is made in Section 4.20.6.5 of the ER, "An additional EDG cooling source may be cost beneficial for Quad Cities." However, the analysis indicates that there is no benefit (averted risk). Explain why there is no benefit, and also explain why it was believed that such an improvement would be cost beneficial when there is no benefit."

Section 4.20.6.5 of the ER only included the statement referenced above as a prelude to the Phase II analysis to introduce the potential benefit. The ER would have been clearer if the second paragraph of Section 4.20.6.5 was not included. Based on the Phase II analysis, the potential change was determined not to be cost beneficial. The negligible benefit results from the fact that the DGCW system supports EDG 1, EDG 2, and the swing diesel, EDG 1/2, but the two Unit SBO DGs are air-cooled via a separate ventilation system that does not require DGCW. Hence, the diversification that would potentially be provided by an alternate DGCW system is already implemented at Quad with the SBO DGs.

Response 13(d):

"For several Phase 2 SAMAs (6, 10, and 14), it appears that a majority of the effort would be in writing/revising procedures and training, and engineering work. Given the additional benefit of these SAMAs in external events and the impact of uncertainties, the benefit of these SAMAs could be substantially higher than assumed in the ER. Explain why these SAMAs would not be cost beneficial when the benefits associated with external events, and the impact of uncertainties are considered."

See the revised disposition provided in Response 7(c) that includes the potential benefits for all of the Phase II SAMAs when external events and uncertainties are also considered.

ATTACHMENT A
FIRE PRA AND USE OF QUANTITATIVE RISK ESTIMATES

Overview

The following summarizes fire PRA topics where quantification of the associated figure of merit, CDF, may introduce different levels of modeling uncertainty than the internal events PRA.

The uncertainties generally reflect the following:

- lack of adequate data for initiating events
- lack of realistic fire modeling capabilities including mitigation
- lack of ability to track all cables (e.g., BOP cables)
- uncertainty in crew response, especially for control room fires, and their modeling
- limited peer reviews that examine the need for realism instead of conservatism

In many cases, analysts choose to address these uncertainties by incorporating margin into the analysis (i.e., conservative assumptions).

Elements of Fire PRA

Fire PRAs are useful tools to identify design or procedural items that could be clear areas of focus for improving the safety of the plant. Fire PRAs use a structure and quantification technique similar to that used in the internal events PRA.

Since less attention historically has been paid to fire PRAs, conservative modeling is common in a number of areas of the fire analysis to provide a "bounding" methodology for fires. This concept is contrary to the base internal events PRA which has had more analytical development and is judged to be closer to a realistic assessment (i.e., not conservative) of the plant.

There are a number of fire PRA topics involving technical inputs, data, and modeling that prevent the effective comparison of the calculated core damage frequency figure of merit between the internal events PRA and the fire PRA. These areas are identified as follows:

Initiating Events: The frequency of fires and their severity are generally conservatively overestimated. A revised NRC fire events database indicates the trend toward lower frequency and less severe fires. This trend reflects the improved housekeeping, reduction in transient fire hazards, and other improved fire protection steps at utilities.

System Response: Fire protection measures such a sprinklers, CO_2, and fire brigades may be given minimal (conservative) credit in their ability to limit the spread of a fire.

Cable routings are typically characterized conservatively because of the lack of data regarding the routing of cables or the lack of the analytic modeling to represent the different routings. This leads to limited credit

	for balance of plant systems that are extremely important in CDF mitigation.
Fire Modeling:	Fire damage and fire spread are conservatively characterized. Fire modeling presents bounding approaches regarding the fire immediate effects (e.g., all cables in a tray are always failed for a cable tray fire) and fire propagation.
HRA:	There is little industry experience with crew actions under conditions of the types of fires modeled in fire PRAs. This has led to conservative characterization of crew actions in fire PRAs. Because the CDF is strongly correlated with crew actions, this conservatism has a profound influence on the calculated fire PRA results.
Level of Detail:	The fire PRAs may have reduced level of detail in the mitigation of the initiating event and consequential system damage.
Quality of Model:	The peer review process for fire PRAs is less well developed than for internal events PRAs. For example, no industry standard, such as NEI 00-02, exists for the structured peer review of a fire PRA. This may lead to less assurance of the realism of the model.

Summary and Conclusions

The fire PRA may be subject to more modeling uncertainty than the internal events PRA evaluations. While the fire PRA is generally self-consistent within its calculational framework, the fire PRA does not compare well with internal events PRAs because of the number of conservatisms that have been included in the fire PRA process. Therefore, the use of the fire PRA figure of merit as a reflection of CDF may be inappropriate. Any use of fire PRA results and insights should consider areas where the "state of the art" in fire PRAs is less evolved than other PRA topics.

Relative modeling uncertainty is expected to narrow substantially in the future as more experience is gained in the development and implementation of methods and techniques for modeling fire accident progression and the underlying data.

Until that time, however, the following assessment is made to provide a methodology for estimating the conservatisms included in the reported Fire PRA CDF numbers for Quad Cities when compared to the internal events CDF numbers.

Initiating Events

A review of a recent NRC report [Reference A-1] was made to obtain an estimate of potential reductions in the fire initiating event frequencies that may occur if more recent and less conservative data were utilized in the Quad Cities analysis. Note that the NRC report only presents the data in the form of fire frequency by major plant location. (It does not provide a breakdown by component such as that which was utilized for the Quad Cities analysis.) As such, a direct comparison is not possible, but if all of the areas listed for each plant location are added up for Quad Cities and placed into one of the categories provided in the NRC report, then an approximate comparison can be made. Table A-1 provides the comparison, and as can be seen, in all areas, the NRC reported frequency per area is lower than that which was utilized in the Quad Cities analysis reflecting both the conservatism of the QC approach and the improving condition of plants in the area of fire protection.

Table A-1
Comparison of Recent NRC Report Fire Initiating Event Frequencies with Quad Cities IPEEE Values

Location	NRC [A-1]	Quad Cities	Ratio (QC / NRC)
Reactor Building	2.8E-2	1.0E-1 / (2 Units) = 5.0E-2	1.8
Turbine Building	4.1E-2	1.9E-1 / (2 Units) = 9.5E-2	2.3
Control Room	7.2E-3	2.5E-2	3.5
Cable Spreading Room	8.4E-4	7.6E-3	9.0
Switchgear Rooms	5.1E-3	1.7E-2 / (2 Units) = 8.5E-3	1.7
EDG Building	1.4E-2	3.6E-2 per room	2.6
SWS Pumphouse	7.2E-3	3.3E-2	4.6
Battery Room	8.4E-4	3.3E-3 per room	3.9
Other	N/A	1.5E-2	N/A

Therefore, based on the comparison provided in Table A-1, it is judged that a factor of two reduction on the Initiating Event frequency portion of the Fire CDF can be made as a reasonable assumption to provide a more accurate comparison to the internal events CDF.

System Response / Fire Modeling

The Quad Cities Fire modeling typically utilized bounding approaches regarding the fire immediate effects (e.g., all cables in a tray are always failed for a cable tray fire, and all failed cables lead to failure states of the associated equipment). In the analysis, severity factors were utilized in some cases to distinguish between large versus small fires, and therefore the consequences associated with each. However, the complement of the severity factor was also maintained in the Quad Cities analysis such that the total frequency was always accounted. The NRC data would support lower initial fire frequencies and lower severity factors in an updated analysis that would lead to lower frequencies associated with many of the dominant fire scenarios. While no direct comparison can be made to approximate the effects this has on the Fire CDF, it is estimated that this modeling approach can also be characterized by at least a factor of two reduction in the Fire CDF to provide a more accurate comparison to the internal events CDF.

HRA / Level of Detail

An examination of the dominant fire scenarios for Quad Cities from the IPEEE indicates that approximately 80% of the reported CDF (excluding Control Room fires) is due to Loss of Containment Heat Removal scenarios. These scenarios are conservative in nature since they involve many hours to evolve (i.e., >24 hours) at which time many ad hoc procedures could be written or previously failed systems could be recovered. In the Quad Cities fire analysis, system recovery was not credited at all for these scenarios.

As a comparison, the Quad Cities internal events model does credit recovery of instrument air to support venting whereas this was conservatively totally excluded from the Fire CDF. Other PRA models have also credited recovery of failed systems (e.g., RHR pumps) in support of scenarios such as the dominant loss of containment heat removal scenarios. Such recoveries were also excluded from the reported Quad Cities Fire CDF since the fire damage could preclude such recovery actions. However, such recovery actions are not precluded per se from other (i.e., non fire-related) failures that exist in the cutsets leading to core damage. Typical non-recovery values for these types of scenarios range from 0.1 to 0.4.

Other dominant scenarios in the Quad Cities fire model included operator action failures that are based solely on the direction provided in the EOPs and Off-normal procedures that are credited in the internal events model. Additionally, the Safe Shutdown Procedures that exist for potential fires in all fire areas were not credited at all in the Quad Cities fire analysis. Credit for these procedures also has the potential for reducing the HEP values utilized in the Fire analysis since they may provide more timely cues or actions to consider given a fire in a specific area compared to the cues that would arise from the symptom-based EOPs.

Considering all of these effects together, it is judged that the simplified HRA modeling and lack of sufficient level of detail in the model can easily lead to an additional factor of three reduction in the Fire CDF to provide a more accurate comparison to the internal events CDF. This can be supported by noting that a 0.2 non-recovery factor on the Loss of Containment Heat Removal cases would allow for long term (>24 hours) response for repair and alternate mitigation. This alone would lead to about a factor of three reduction in the total Fire CDF for Quad Cities.

Combined Impact for Comparison to the Internal Events CDF

The CDF contribution to internal fires was estimated at 6.6E-5/yr for Unit 1 and 7.3E-5/yr for Unit 2 in the Quad Cities IPEEE submittal. Using the Unit 2 value as a bounding case, and the reduction factors provided above, the following assessment is made.

Reported Fire CDF:
7.3E-5/ yr

Reduction from Conservatisms in the Initiating Event frequencies and System Response (2):
7.3E-5/yr / 2 = 3.65E-5/yr

Reduction from Conservatisms in Fire Modeling (2):
3.65E-5/yr / 2 = 1.83E-5/yr

Reduction from HRA Simplifications and Lack of Detail in the Scenario Modeling (3):
1.83E-5/yr / 3 = 6.1E-6/yr

Considering all of the conservatisms in the reported Fire CDF indicates that if the fire results were recalculated to remove excess conservatisms for Quad Cities, then the fire CDF result would decrease to be well within a factor of three (i.e., 6.1E-6/yr / 2.2E-6/yr = 2.8, or approximately 3) of the internal events CDF. This conclusion is supported by the discussion above.

REFERENCES

[A-1] U.S. Nuclear Regulatory Commission (Division of Risk Analysis and Applications), "Fire Events - Update of U.S. Operating Experience, 1986-1999; Commercial Power Reactors", RES/OERAB/S02-01, January 2002.

Attachment 2

RAI Responses Related to Transmission Lines

RAI 1a

Regarding the consideration of electric shock:

The staff has determined that NRC regulations, specifically 10 CFR 51.53(C)(3)(ii)(H), require the consideration of electric shock for all transmission lines constructed for the specific purpose of connecting the plant to the transmission system. The staff recognizes the Final Environmental Statement (FES) for initial plant operation states in Section V.A.3 that according to the applicant, approximately 45 miles of transmission line were planned and would have been built even if the Quad Cities station had not been built. However, the FES also states in Section III.B that these lines were planned and would have been built to an alternate source of power in the area had the Quad Cities station not been built. Therefore, the staff's understanding is that the lines were constructed for the specific purpose of connecting the plant to the transmission system. The staff has determined that 10 CFR 51.53(C)(3)(ii)(H) requires the Quad Cities license renewal ER to include consideration of 27 miles of the Davenport line (0401) to Substation 56 and 17.5 miles of the Barstow line (0402) to Substation 39. Similarly, the consideration of electric shock is required for both Nelson lines (0403 which traverses 41.9 miles to the Nelson substation, and 0404 which traverses 39.7 miles to the to the Nelson substation).

Response 1a:

EGC has performed the analysis of the electric field strength, as described in the ER Section 4.13, for those sections of the transmission lines not previously analyzed in the ER but that are listed in the Final Environmental Statement for initial plant operation in section V.A.3. The results of this analysis has determined that the lines conform to the National Electric Safety Code (NESC) provisions for preventing electric shock from induced current.

The following represents the induced current, in milliamperes (ma), for those sections not previously analyzed in the ER:

Davenport (0401), Substation 56 to Substation 91	4.5 ma
Barstow (0402), beyond the Cordova Substation	4.6 ma
Nelson South (0403), beyond the Cordova Substation	4.7 ma
Nelson North (0404), beyond Northwest Steel and Wire	4.7 ma

RAI 1b

Also, during its review, the staff noted in Table 4-3 of the ER that one transmission line (0404) is not in conformance with the recommendation of the National Electric Safety Code (NESC) for preventing electric shock from induced current. The staff is not persuaded by the discussion in ER Section 4.13 regarding the absence of a need for mitigation measures. Please describe the measures which will be taken to mitigate the non-conformance of the 0404 line with the NESC recommendation.

Response 1b:

As stated in the ER, EGC does not own, operate, or maintain the transmission line that is the subject of this request for information.

Possible mitigation measures, or combinations, that could be taken to reduce the electric shock from induced current include:

- Removing the line from service, or
- Raising the transmission lines to reduce proximity to the line, or
- Lowering the road to reduce proximity to the transmission line, or
- De-rating the line such that conditions that lend the line to producing the induced current hazard are not encountered, or
- Limiting access to travel on the road to vehicles that do not lend themselves to higher levels of induced current, or
- Posting of warning signs to warn of the potential hazard.

Because EGC does not own, operate, or maintain the transmission line, EGC does not have the ability to implement any of the above possible mitigation measures.

RAI 2

Regarding the applicability of the Endangered Species Act (ESA) to various portions of the transmission lines, the staff articulated a position which was documented in a letter from Cynthia A Carpenter, NRC, to Mr. William R. McCollum, Jr., Duke Energy Corporation, dated May 10, 1999, during the review of the Oconee license renewal application. Specifically, the ESA is applicable to the same areas of the transmission system which are subject to the NRC regulation regarding electric shock. Please provide additional information regarding threatened and endangered species for the portions of the transmission system identified above in the request regarding consideration of electric shock.

Response 2:

With respect to the transmission lines that are listed in the Final Environmental Statement for initial plant operation in section V.A.3, EGC is aware of no resident threatened or endangered terrestrial species being present along the associated transmission corridors. The presence of transient species is possible, but EGC is aware of no transmission line activities related to license renewal that would alter the conclusion stated in the Environmental Report that QCNPS has no adverse impacts on threatened or endangered species.