Appendix E

SAMA ANALYSIS

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Acronyms Used in Appendix E

ASME	American Society of Mechanical Engineers
ATWS	anticipated transient without scram
BE	basic event
BWR	boiling water reactor
CC	component cooling
CDB	core damage bin
CDF	core damage frequency
CET	containment event tree
CRD	control rod drive
CS	core spray
CST	condensate storage tank
DG	diesel generator
ECCS	emergency core cooling system
EDG	emergency diesel generator
EE	external events
EG	emergency generator
EPRI	Electric Power Research Institute
EPZ	emergency planning zone
ET	event tree
F&O	fact and observation
FP	fire protection
FT	fault tree
FRVS	filtration, recirculation and ventilation system
HCGS	Hope Creek Generating Station
HEP	human error probability
HRA	human reliability analysis
HVAC	heating ventilation and air-conditioning
IA	instrument air
IE	initiating event
IPE	individual plant examination
IPEEE	individual plant examination – external events
ISLOCA	interfacing system LOCA
LERF	large early release frequency
LOCA	loss of coolant accident
LOFW	loss of feedwater
LOOP	loss of off-site power
MAAP	modular accident analysis program
MACCS2	MELCOR accident consequences code system, version 2
MACR	maximum averted cost-risk
MG	motor generator
MMACR	modified maximum averted cost-risk
MOR	model of record
MOV	motor operated valve
MSIV	main steam isolation valve

Acronyms Used in Appendix E

MSPI	mitigating systems performance indicator
NEI	Nuclear Energy Institute
NPSH	net positive suction head
NRC	U.S. Nuclear Regulatory Commission
OECR	off-site economic cost risk
PACR	potential averted cost-risk
PRA	probabilistic risk analysis
PSA	probabilistic safety assessment
PSEG	Public Service Enterprise Group
PWR	pressurized water reactor
RB	reactor building
RCS	reactor coolant system
RDR	real discount rate
RHR	residual heat removal
RPV	reactor pressure vessel
RRW	risk reduction worth
RACS	reactor auxiliaries cooling system
SAMA	severe accident mitigation alternative
SACS	safety auxiliaries cooling system
SAG	severe accident guidelines
SBO	station blackout
SDS	seismic damage states
SRV	safety relief valve
SSW	station service water
SW	service water
SWGR	switchgear

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SEVERE ACCIDENT MITIGATION ALTERNATIVES

The severe accident mitigation alternatives (SAMA) analysis discussed in Section 4.20 of the Environmental Report is presented below.

E.1 METHODOLOGY

The methodology selected for this analysis involves identifying SAMA candidates that have potential for reducing plant risk and determining whether or not the implementation of those candidates is beneficial on a cost-risk reduction basis. The metrics chosen to represent plant risk include the core damage frequency (CDF), the dose-risk, and the offsite economic cost-risk. These values provide a measure of both the likelihood and consequences of a core damage event.

The SAMA process consists of the following steps:

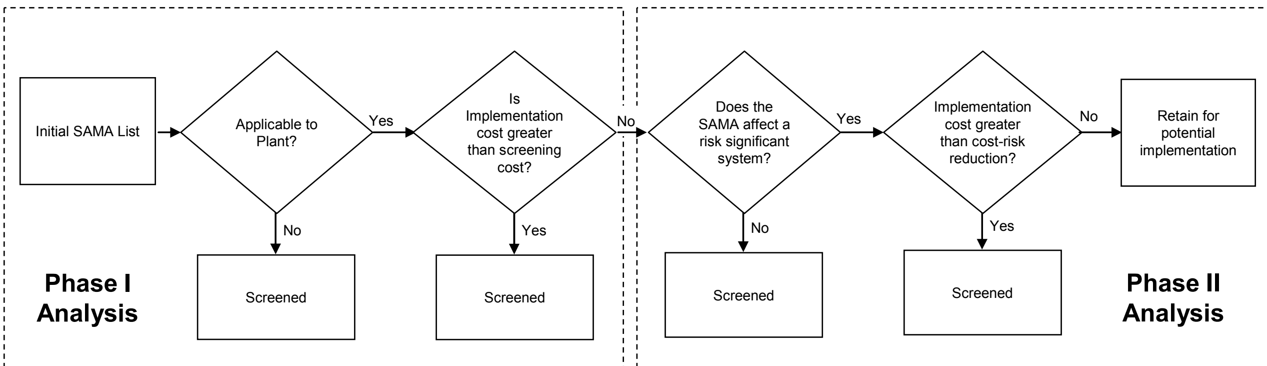
- Hope Creek Generating Station (HCGS) Probabilistic Risk Assessment (PRA) Model – Use the HCGS Internal Events PRA model as the basis for the analysis (Section E.2). Incorporate External Events contributions as described in Section E.4.6.2.
- Level 3 PRA Analysis – Use HCGS Level 1 and 2 Internal Events PRA output and site-specific meteorology, demographic, land use, and emergency response data as input in performing a Level 3 PRA using the MELCOR Accident Consequences Code System Version 2 (MACCS2) (Section E.3). Incorporate External Events contributions as described in Section E.4.6.2.
- Baseline Risk Monetization – Use U.S. Nuclear Regulatory Commission (NRC) regulatory analysis techniques to calculate the monetary value of the unmitigated HCGS severe accident risk. This becomes the maximum averted cost-risk that is possible (Section E.4).
- Phase 1 SAMA Analysis – Identify potential SAMA candidates based on the HCGS Probabilistic Risk Assessment (PRA), Individual Plant Examination – External Events (IPEEE), and documentation from the industry and the NRC. Screen out SAMA candidates that are not applicable to the HCGS design or are of low benefit in boiling water reactors (BWRs) such as HCGS, candidates that have already been implemented at HCGS or whose benefits have been achieved at HCGS using other means, and candidates whose estimated cost exceeds the maximum possible averted cost-risk (Section E.5).
- Phase 2 SAMA Analysis – Calculate the risk reduction attributable to each of the remaining SAMA candidates and compare to the estimated cost of implementation

to identify the net cost-benefit. PRA insights are also used to screen SAMA candidates in this phase (Section E.6).

- Uncertainty Analysis – Evaluate how changes in the SAMA analysis assumptions might affect the cost-benefit evaluation (Section E.7).
- Conclusions – Summarize results and identify conclusions (Section E.8).

The steps outlined above are described in more detail in the subsections of this appendix. The graphic below summarizes the high level steps of the SAMA process.

SAMA SCREENING PROCESS



E.2 HOPE CREEK PRA MODEL

The SAMA analysis is based upon the 2008 update of the HCGS PSA model for internal events (i.e., HC108B model). The original IPE model was submitted in 1994 has been subsequently updated in 1994, 1999, 2000, 2003, 2004, 2005, 2006 and 2008 to maintain the design fidelity with the operating plant and reflect the latest PRA technology.

The following subsections provide more detailed information related to the evolution of the Hope Creek Internal Events PRA model and the current results. These topics include:

- PRA changes since the IPE
- Level 1 model overview
- Level 2 model overview
- PRA model review summary

Section E.4.6.2 and E.5.1.7 provides a description of the process used to integrate external events contribution into the Hope Creek SAMA process.

Table E.2-1 provides a summary of the models created since the IPE.

E.2.1 PRA MODEL SINCE IPE SUBMITTAL (PSEG 1994a)

The IPE submittal (PSEG 1994a) presented a summary of the Level 1 and Level 2 PSA analyses per GL 88-20 (NRC 1991a) and the IPE submittal guidance in NUREG 1335 (NRC 1989). The study was performed and documented in accordance with the guidance provided in NUREG/CR-2300 (NRC 1983). Also presented were a description of the review process, insights learned through the IPE process, PSEG management plans for the future use of the HCGS PSA, and the insights gained through the IPE process.

E.2.1.1 PRA MODEL 0 UPDATE (PSEG 1994b)

The Hope Creek PRA Model was updated in September of 1994 and identified as Rev 0. As documented in this revision to the PSA, this model represents “the second tier documentation of the Individual Plant Examination (IPE) for the HCGS.”

E.2.1.2 PRA MODEL 1.0 UPDATE (PSEG 1999)

During 1999, PSEG participated in a PRA Peer Review Certification of the Hope Creek PRA administered under the auspices of the BWROG Peer Certification Committee. The purpose of the PRA peer review process is to establish a method of assessing the technical quality of the PRA for the spectrum of its potential applications. In responding to the team comments and to incorporate plant modifications, the HCGS PRA updating was initiated in 1998. During the update, recent NRC and industry studies and findings were incorporated.

The major changes finished in this update were directed towards the Level II approach. This update integrated Level I and II. The Level I core damage sequences are categorized with the plant damage class (PDC). Sequences within one category are merged and directly used in the Level II for further analysis. The integrated approach facilitates future applications and information transfers between the Level I and II analysis.

Other important tasks accomplished in this update were:

- The database is largely updated with a consistent approach for all basic events used in the PSA model. The generic data is carefully selected and plant specific experience is used for updating.
- The sequence is further developed and the end states are either cold shutdown or core damage.
- Fault trees are developed for all special initiators.
- Cutsets containing two or more operator actions are reviewed and documented.

The following analyses were retained form the past analysis.

- Interfacing System Loss of Coolant Accidents (ISLOCA).
- The containment capacity analysis.
- Internal flooding analysis.

E.2.1.3 PRA MODEL 1.1 UPDATE (PSEG 2000a)

In 2000, a minor revision of the PSA was completed. The CDF was recalculated although the LERF was not updated in Revision 1.1 of the PRA model.

The following text documents the specific changes made in the PSA Model 1.1 update.

E.2.1.3.1 Basic Event Changes

- NR-ATWS-ADS-INH - The diagnosis error for failing to inhibit ADS is negligible (Appendix H) and on the basis that it is a virtual automatic response based on training and it is explicitly called out in LP-2 in 207 or RC/Q-19 in 101 EOP. Failure to perform is also considered negligible based on the simplicity of the actions, simulator results, and feedback from the alarm when the actions have been successfully performed. Also based on HEP of Grand Gulf and Fitzpatrick that each assigned a value less than 1.0E-05, it is concluded that the value of 7.5E-2 that was originally assigned is too conservative. Therefore the value of 1.0E-04 is assigned for this action.
- NR-SACS-SHED-01 - Human error recovery event NR-SACS-SHED-01 is re-quantified. The restoration of SACS is described in procedure No. HC.OP-AB.ZZ-0124 (Q). The Hope Creek PSA assumed that the earliest this action is required is at least 2 hours after the initiation of transient (TM= 2 hours Appendix H HCGS PSA Rev.O.) and because local nature of the action, a performance time of 1 hour is assumed. Based on NUREG/CR-4772 (NRC 1987) Table 8-1, a diagnosis BHEP of 1.0E-03 is assumed since the actual performance would only be required when the ultimate heat sink temperature (River Temperature) is high and time is not curtail. It is assumed that this action can be considered a critical action as part of a step-by-step task done under moderately high stress. Therefore an action BHEP of 0.02 is assigned, taken from Table 8-5 of NUREG/CR-4772. A recovery factor of 0.001 is applied to the action BHEP, taken from item 10 of the same table. This results in a total HEP of HEP = 1.0E-03 + 0.02 * 0.001= 0.00102 ≈ 0.001 = 1.0E-03
- NR-RHR-INIT - The quantification of post-accident operator error, NR-RHR-INIT is described in detail in the Hope Creek PSA, Appendix H. In the calculation summary for the event, it is noted that NUREG/CR-1278 (NRC 1985), the most appropriate methodology can be used to calculate a human error probability as low as 2.0E-06. However later more conservative number 2.0E-04 is used based on Table 9-1 of NUREG/CR-4772 that provides the results of the HEP calculation for failure to initiate SPC given RHR was already placed in service for injection by using NUREG/CR-1278 methodology. The post-accident human error NR-RHR-INIT included not only SPC, but also SDC and CSC. For each of these independent actions (SDC and CSC) the value of 0.1 from the NUREG/CR-1278 Chapter 20 is assigned for each action. This results in a total HEP of 2.0E-04 *0.1 *0.1 = 2.0E-06
- CHC-LOOPB-ACTUAT - The basic event CHC-XHE-FO-LOOPB with failure probability of 1.0E-01 is replaced by basic event CHC-LOOPB-ACTUAT with failure probability of 3.0E-03.
- NR-XTIE-EDG - It is noted in NUREG/CR-1278, that the most appropriate methodology can be used to calculate a Human Error Probability using written procedures under abnormal operating condition. The more conservative value predicted is using NUREG/CR-4772 Table 8-5 which performing a critical action as

part of a dynamic task done under extremely high stress. Table 8-5 provides the results of the HEP calculation for this action. The value of the quantified HEP is 0.25. The more conservative value of 0.3 is recommended for this action.

Fault Tree Changes

- The fault trees IE-HVAC.LGC, CHCA.LGC, CHCB.LGC, ZCHCA.LGC, ZCHCB.LGC, SWA.LGC, and SWB.LGC are changed to make the fault trees symmetrical.
- The basic event NR-DG-DF-6 is removed from fault tree SDGA.LGC. The basic event RHS-XHE-FO-SDC is replaced by NR-RHR-INIT in fault tree SDC.LGC. The basic event NR-VENT-5 is replaced by basic event NR-RHR-INIT in fault tree CONTVENT.LGC. The basic event NR-SW is removed from fault tree SWSA--HVC.LGC. The basic event NR-DG-DF-6 is added to fault tree EDG-TOP.LGC.

Safety Auxiliaries Cooling System (SACS)

- System Function
  - The Safety Auxiliaries Cooling System (SACS) is a closed loop cooling system designed to supply cooling water to various safety-related equipment during all plant operating modes. The system is a part of the overall system called the Safety and Turbine Auxiliaries Cooling System (STACS), which also supplies cooling water to various auxiliary equipment during normal operation and various shutdown conditions The STACS consists of two redundant loops. A simplified diagram of STACS is presented in Figure 3.2-15. Each STACS loop contains two pumps, two heat exchangers, one expansion tank, one demineralizer, and one chemical addition tank, in addition to pipes and valves. The pumps circulate the demineralized cooling water through components and equipment. The circulating water is cooled by the station service water system in the SACS heat exchangers. Each SACS loop is completely independent of the other, eliminating the possibility of a single failure causing the loss of the entire system.
- SACS Success Criteria:
  - SACS loops is considered successful in providing cooling flow if either of the following conditions are met
- Loop Operation: Two pumps and two heat exchangers in one loop are in operation. The other loop can be INOP completely. The SACS loop cross-ties are only meaningful in this configuration. Operator must re-align heat load arrangement in order to be successful. Or One pump and two heat exchangers in one loop and One pump and one heat exchanger in the other loop must be in operation. This configuration is successful with some load shedding. This configuration is denoted as Configuration I-I.
- Related Fault tree Changes
  - The following fault trees are changed to include changes in SACS system success criteria. CHCA, CHCB, CHSA, CHSB, CSA-RMLC, CSB-RMLC, CSC-RMLC, CSD-RMLD, CSC, HPI-RMLC, IAS, IGASA, IGASB, LPI, RCI-RMLC, RHA-RMLC, RHB-RMLC, RHC-RMLC, RHD-RMLC, SDGA, SDGB, SDGC, SDGD, U-TOP-N, ZCHCA AND ZCHCB.

TSC Chiller Room Cooler

- The dependency of SAC A, B, C, and D on room cooler are deleted. The Chillers supply cooling to the 1E panel room. The room has panel lAJ 482, IBJ482, 1CJ482, and IDJ482 which supply power to control logic of SACS Pumps A, B, C, and D (See Table T-11 of CBD DE-CB.EG-0054). In case of TSC Chiller failure, the room will heat up and the control panels will fail in 20 minutes (see Calculation GM-3). Therefore the TSC chiller model is needed for SACS pumps to function. The two fault trees ZCHSA, ZCHSB were built similar to ZCHA and ZCHB to reflect the TSC Chiller. In the Chiller model we take the credit of operator action to bring portable fans in case of loss of both TSC Chillers (See Loss of HVAC HC.OP-AB.ZZ-0154(Q) 1/15/99).

CONDENSATE

- When the relief valves stuck open the condensate System can not be credited. This dependency was removed in cases that relief valves stuck open. The fault tree UV-TRAS was changed to reflect these changes.
- In fault trees IE-HAVC, CHCA, CHCB, IAS, ZCHCA, ZCHCB, and CHSB, the basic event CHC-XHE-MC-FTAl, or 3 are deleted. The basic event CHC-LOOPA or B-ACTUAT includes operator fail to start and failure of auto start. The basic event CHCXHE-MC-FTA1, or 3 is included in basic event CHC-LOOPA or B-ACTUAT.
- The Basic event VAS-FAN-FS-CV2l4 in fault tree SACA-RCL was used for both fan A and C. The correct basic event for fan A is VAS-FAN-FS-AV2l4. Therefore the basic event for fan A is changed to VAS-FAN-FS-AV214.
- The Disallow maintenance fault tree was revised to include mutually exclusive events such as two train SACS, two trains SW Pumps.

<u>Event Tree Changes</u>

The event trees T(T), T(M), T(C), T(RA) were changed in order not to credit from the Condensate System when the relief valves stuck open.

<u>Specific Documentation Changes</u>

Section 1 -Project Integration

This section was not revised. However, it should be noted that during Rev. 1.1 the PSA Level II was not updated. Hence, the results mentioned in this document for Level II are not accurate.

Section 2.0 -Methodology

The methodology remains the same.

Section 3.0 System Analysis

Section 3.1

1. With the exception of the ATWS, large LOCA, loss of HVAC, loss of offsite power, and the IAS tree, all the remaining event trees are changed structurally. Also, all the values of sequences for all the event trees have changed. The main reason for structural changes is that no credit is taken for the condensate pumps in sequences that lead to high containment pressure. All the event trees are replaced with new trees in this section.

2. The write-up in this section is revised to reflect the new sequences, new Bed

3. files, and new results.

4. Table 3.1.2-3 is revised to reflect the new bed files used in various trees. New VU events are introduced, as discussed in the "Alternative Low pressure Makeup-VU" section

Section 3.2

1. Section 3.2.1.7.9.2 is modified to indicate that success of Condensate system requires that the containment pressure not exceed 1.68 psig, so the TACS cooling to the secondary condensate pump become available.

2. Section 3.2.1.15.3 is revised to reflect that SACS pumps can operate for 24 hours without room cooling.

3. Section 3.2.1.15.9.2 is revised to reflect the new success criteria for the SACS system, and the affected fault tree models.

4. A new reference is used in Section 3.2.1.15.10 of PRA Model Revision 1.1.

5. Section 3.2.1.21.1 is revised to reflect the new findings about the fault tree naming convention which had affected the PSA model for some time; this finding had affected the Equipment Area Cooling System (EACS) to the extent that the code would not show dependency of the model to this system, at all.

6. Table 3.2-6 was revised to reflect the addition of new house events in the model.

Section 3.3

1. Table 3.3.3-8 is revised to reflect addition of human recovery actions modeled.

2. Table 3.3.7-1 is revised to show new equations used in the model, as well as their new cut off frequencies.

Section 3.4

Section 3.4 is revised entirely, and the write-up reflects the new results.

Section 4.0

The backend analysis is not repeated for Revision 1.1. Hence, the results shown in this section are not applicable anymore. However, the Level II discussion continues to hold true for the most part. Table 4.3.3 is deleted with revision marks. This is also true with Section 4.7.2.

Section 5.0

This section is almost the same as Section 3.4; hence, it was revised to reflect the new finalized results.

Appendix A

No Change.

Appendix B

Revision 1 was finalized on June 6, 1999. All the fault trees that have a different date are related to revision 1.1. These can be easily identified in Appendix B, since they show up with the new Revision 1.1 markup, and have new dates on them. RA Model 1.2 Update

E.2.1.4 PRA MODEL 1.2 UPDATE (PSEG 2000b)

In June of 2000, another minor revision of the PSA was completed. The CDF was recalculated in this revision. Although the LERF was not updated in Revision 1.1 of the PSA model, Revision 1.2 provides an estimate.

The following text documents the specific changes made in the PSA Model 1.2 update.

Section 3.0 FRONT-END ANALYSIS

Section 3.1 Accident Sequence Delineation

1. Defined and developed the frequency for the following two new initiating events:
   a) Steam/Water Line Break Outside of Containment (BOC),
   b) Manual Shutdown (SD).

2. Bayesian Updated the frequency, using Hope Creek plant specific data, for the following two initiating events:
   a) Turbine Trip,
   b) Loss of Offsite Power.

3. ATWS Model has been modified significantly.

4. Two new event tree models have been added. These models are Steam/Water Line Break Outside of Containment and Manual Shutdown.

5. Sections 3.1.1.4.2 and 3.1.1.4.4 were revised to include information on the PCS and reopening the MSIVs.

6. Section 3.1.1.4.12 was revised so it does not indicate that the PCS can be recovered.

7. Section 3.1.2.1.3 was revised to state that the PCS will be available if the drywell does not exceed 1.68 psig (it is not expected to exceed this pressure).

8. Section 3.1.2.1.5 was revised not to state that feedwater can be recovered and that the PCS is not expected to be recovered and is not modeled.

Section 3.2 System Analysis

1. The SACS cooling requirement for the core spray room coolers are removed.

2. SACS fault tree descriptions are removed from the main text and are referred to the Hope Creek notebook.

3. SLC success criteria are clearly re-stated to use two SLC pumps.

Section 3.3 Quantification Process

Table 3.3.3-8 is revised to reflect all human recovery actions modeled in Level I and II of the PSA

Section 3.4 Front-End Results

Section 3.4 has been re-written.

Definition of LERF is clarified, and supporting analysis for classification of each plant damage class is provided in Table 3.4-2.

Section 4.0 BACK-END ANALYSIS

Section 4.7 has been re-written.

Section 5.0 SUMMARY OF RESULTS AND FINDINGS

This section is the same as Section 3.4; hence, it was revised to reflect the new finalized results.

Appendix B

Some changes have been made to the HCGS fault trees. See Section 3.2 of the HCGS PSA for more detailed information.

Appendix D

1. Table D-I, "HCGS Plant Specific Data Analysis For Component Failure", was revised. The primary changes in plant specific data involved the HPI, RCI, RHS, and CSS Suppression Pool Strainers.

2. Table D-4a, “Special Events Used In The Level I Analysis”, was revised. Below provides the primary changes to this table:

   a. Added basic event CAC-BOC-SY-FREQ, "BOC BREAK ISO FAILURE".

   b. Added basic event HPI-BOC-SY-FREQ, "BOC DUE TO HPCIJRCIC OR RWCU".

   c. Added basic event MSI-BOC-SY-FREQ, "BOC DUE TO MSIV". Changed probability for basic event PCS-SPE-EHC-FAIL, "EHC

   d. FOR BYPASS VALVES FAILS".

3. Table D-4b, "Special Events Used In The Level II Analysis" was revised. The Level II special event probabilities are developed separate from the Data Analysis task. The Level II special events are discussed in the Back-End Analysis presented in Section

4 of the HCGS PSA report. For convenience, Table D-4b summarizes the special event probabilities used in the Level II analysis.

Appendix E

1. The scope of identifying Common Cause Failure (CCF) events expanded to include redundant, similar components within inter-systems (i.e., HPI, RCI, RHS, and CSS Suppression Pool Strainers).

2. Table E-2, "Common Cause Failure Analysis For The HCGS PSA", was revised. The following describes the primary changes to this table:

   a. Added CCF basic event SAC-MDP-FR-DF08, "SACS A -B -C PUMPS FAIL TO RUN".

   b. Added CCF basic event SAC-MDP-FR-DF09, "SACS A -B -D PUMPS FAIL TO RUN".

   c. Added CCF basic event SAC-MDP-FR-DF10, "SACS A -C -D PUMPS FAIL TO RUN".

   d. Added CCF basic event SAC-MDP-FR-DFll, "SACS B -C -D PUMPS FAIL TO RUN".

   e. Added CCF basic event SAC-MDP-FS-DF08, "SACS A -B -C PUMPS FAIL TO START'.

   f. Added CCF basic event SAC-MDP-FS-DF09, "SACS A -B -D PUMPS FAIL TO START".

   g. Added CCF basic event SAC-MDP-FS-DF10, "SACS A -C -D PUMPS FAIL TO START".

   h. Added CCF basic event SAC-MDP-FS-DF11, "SACS B -C -D PUMPS FAIL TO START".

   i. Added CCF basic event HPI-STR-PL-DF01, "CCF FAILURE OF HPCI AND RCIC SUCTION STRAINERS".

   j. Added CCF basic event RHS-STR-PL-DF02, "CCF FAILURE OF CSS AND RHR SUCTION STRAINERS".

   k. The probabilities of various other CCF basic events ·were changed due to changes in their associated independent failure probabilities and due to changes in their associated CCF grouping sizes.

Appendix F

The table presented in this appendix of PRA Model Revision 1.2 is a print out of the HCGS Basic Event Bed File that is used by WinNupra. The changes made to the HCGS Basic Event Bed File reflect the numerous changes made in the HCGS Data Analysis.

Appendix H

This appendix is revised to reflect the new HR events, latest EOP, and Level II HRA.

Appendix I

Some Level II Basic Event probabilities in the fault trees changed. These values are listed in Appendix D, Table D-4b and in Appendix H of PRA Model Revision 1.2.

E.2.1.5 PRA MODEL 1.3 UPDATE (PSEG 2000c)

In October of 2000, another minor revision of the PSA was completed. The CDF was recalculated in this revision. The LERF was also recalculated in this update but was the same answer from Model 1.2.

The following text documents the specific changes made in the PSA Model 1.3 update.

A. SACS Success Criteria:

The detailed description of the SACS/SSWS success criteria is summarized in working file HCOO-OI and in revision summary of version1.2.The brief summary of the modified SACS criteria is described below, item 6 and 7 are the modified criteria used in version 1.3.

The success criteria of the SACS are:

1. 1 full loop with successful alignment of valves to shed load.
2. 1 pump and 2 Hx's in one loop connected to the RHR and 1 pump and 1 HX in the other loop supply to the rest of the heat load.

Thus, the failures are:

1. Failure of 1 loop with unsuccessful load shedding.
2. Failure 3 pumps.
3. Failure 3 Hx's.
4. Failure of 2 pumps in one loop and 1 Hx in another loop.
5. Failure of 2 Hx's in one loop and 1 pump in another loop.

6. Failure of one SACS pump, one heat exchanger in one loop with another SACS pump failure in another loop with operator failure to re-align the valves.
7. Failure of one SACS pump, one heat exchanger in one loop with one heat exchanger failure in another loop.

B. Fault Tree / Event tree Changed

1. sacs-a.lgc Based on the above discussion, the fault tree has been modified.
2. T(sa) event tree –The Loss of SACS/SSWS event tree has been modified. The recovery action (NR-SW) has been moved to the fault tree ie-sws.
3. ie-sacs.lgc fault tree has been modified to correct the failure mode, the failure mode is three out of four SACS trains.
4. Due to the train/system models of EOOS requirements, all trains are now modeled in IAS, SLC, and CRH systems.

C. Top Logic Model Modification due to Full Model Changes

1. Sacs-a.lgc fault tree: Model changes due to success criteria modification. Delete the IE event below the top gate, this change will not affect the result but will speed-up the calculation.
2. page 24 of main fault tree , HCTOPR12.lgc : Fault tree structure is changed due to T(sa) event tree change. Page 25 and 26 are deleted.
3. ie-sacs.lgc fault tree: fault tree has been modified to correct the failure mode, the failure mode is three out of four SACS trains. Corrections are also made to reflect those modeling made in the full model.
4. ias, slc, and crh fault trees are modified to consider symmetry of all trains in these systems.
5. iesws-a.lgc and iesws-b.lgc fault trees -Since these trees are only called by the initiating SSWS/SACS event top gate, all the LOP related events will be deleted in the final calculation (dhos-lop * dhos-nolop). To speed-up the processes, all LOP related gates are manually deleted.
6. ssws-a, ssws-b fault trees – Delete the ie-sws event below the top gate, this change will eliminate the loop error during the fault tree solution.
7. pcs and hpci fault trees -Gates calling the SSWS/SACS initiating event top gate have been modified to call a pseudo gate to speed-up the solution process.
8. ie-top fault tree – a pseudo gate is added to facilitate item 7.

9. Zchsa and zchsb – fault trees are modified to reflect the changes made in full model version 1.2.

D. PSA Application Review:

The previous AOT submittals of SSWS, SACS and EDG systems using the PSA methodology were validated and verified using version 1.3. The risk matrix and 12-week schedule risk matrix are also re-generated (see revised Calcs files). Since the results from this version is less stringent than those generated from previous version, all applications using this version will yield less severe risk than that of the previous version.

E.2.1.6 PRA MODEL 2003A UPDATE (PSEG 2003)

For the 2003A model update, the CAFTA software suite was selected. The conversion of the HCGS NUPRA PRA model to CAFTA was completed in November 2002. This straight conversion involved no model or data changes.

This converted CAFTA model was then used as the starting point for the 2003A model update which was the result of a regularly scheduled update. Major changes included: Completely revised component failure data (including extensive use of plant-specific component failure data) and initiating events data utilizing the latest operating experience. Significant changes to the following elements have been performed to meet the changes needed to respond to the PRA Peer Review and the ASME PRA Standard. These include:

- Complete new HRA using the EPRI HRA Calculator and dependency analysis
- Revised accident sequence definitions (Event Tree)
- New MAAP calculations to support the success criteria and accident sequence timing at the Extended Power Uprate (EPU) configuration
- Updated data (initiating events, component failure data and vulnerability)
- Modified System models
- Updated common cause failures incorporating the latest NRC data
- The addition of internal flood accident sequences

- EPU power level and associated MAAP 4.0.4 calculations to support timing and success criteria changes

E.2.1.7 PRA MODEL 2.0 UPDATE (PSEG 2004)

The PRA Model 2.0 Update was completed in October 2005. The important changes in this model revision are PSEG modifications on 480 VAC dependencies, SACS, success criteria, and SACS-SW HEPs.

E.2.1.8 PRA MODEL 2005 UPDATE (PSEG 2006a)

The updated 2005 PRA Model was revised 3 times (A, B, and C) during 2005 to update the PRA modeling and to address the EPU related risk assessment. The 2005A model, the 2005B, and 2005C PRA models address the following items:

- Remove conservatism in SACS-SW success criteria
- Include more detailed logic for AC power supplies
- Remove conservatism in operator action HEPs to support the EPU submittal

E.2.1.8.1 PRA Model 2005A Update

The 2005A model update was completed in October of 2005. The 2005A update was an interim PRA model to address conservatism in the Rev. 2.0 model and was never officially used for quantification purposes.

E.2.1.8.2 PRA Model 2005B Update

This minor update was completed in November of 2005, only 1 month later than the 2005A model. The PRA 2005B model was used as input for the EPU submittal. This model, like the 2005A update, removes conservatism introduced in the Rev. 2.0 model (e.g., SACS heat load manipulation HEPs).

E.2.1.8.3 PRA Model 2005C Update

The last of the minor 2005 updates is Model 2005C. This model was created due to an unscheduled update to the 2003A PRA model. This revision modifies the 2005B EPU model to support online maintenance evaluations and MSPI calculations. The only PRA model change from the 2005B EPU PRA model to the 2005C Base PRA model is to reduce the turbine trip initiating event frequency from 1.25/yr to 1.03/yr to reflect plant specific operating history.

E.2.1.9 PRA MODEL HC108A UPDATE (PSEG 2008a)

The 2008 PRA Update was performed to satisfy the PSEG internal requirement for a periodic PRA Update and to address open issues such as the ASME PRA standard self-assessment “gaps”, additional UREs, and updated data.

The 2008 periodic update includes:

- A complete update of the initiating events
- A complete revision to the HRA including simulator observations and crew interviews
- Significant modeling changes for the following:
  - Incorporation of plant changes
  - Incorporation of procedure changes
  - Resolution of discrepancies noted in the PRA self-assessment
- A complete update of the data analysis involving common cause

The HCGS 2008 PRA model (HC108A) is the result of upgrading the Hope Creek PRA model. A summary of the changes to the Hope Creek PRA model is included here.

<u>Model Framework</u>

- The CAFTA model framework developed for the 2003A model upgrade is retained for the HC108A model.
- The LERF model has been expanded to a full Level 2 with a full spectrum of radionuclide releases.
- The PRA computer model has been developed within the CAFTA environment. The model exists in two logic formats:
  - sequence model -- PRAQUANT
  - single top fault tree model -- ONE4ALL

<u>Initiating Events</u>

- Bayesian updated initiating event frequencies utilizing the most recent Hope Creek operating experience and latest generic BWR operating experience.
- Allocation of LOCA frequencies on a location and size specific basis (i.e., the LOCA locations have been subdivided for more accurate assessments of their consequences).

- Revised LOOP analysis is performed for initiating event frequencies and non-recovery probabilities including the impact of the 2003 Northeast Blackout using the latest INEEL analysis in NUREG/CR-6890 (NRC 2005) and accounting for local Hope Creek grid operating experience.
- The conditional probability of a LOOP given a transient or LOCA signal event is incorporated into the PRA modeling.

<u>Component Data</u>

- Individual component random failure probabilities Bayesian are updated (as applicable) based upon the most recent plant specific data and the generic sources. This included revised component failure data including extensive use of plant-specific component failure data gathered from the Hope Creek Maintenance Rule program. Generic information from NUREG/CR-6928 (NRC 2007) and NUREG/CR-1715 (NRC 2000) are used when available as the prior distribution to support Bayesian updating.
- Common cause failure (CCF) calculations are revised to incorporate the upgraded individual random basic event probabilities and the most up to date Multiple Greek Letter (MGL) parameters from NUREG/CR-5497 (NRC 1998c) and NUREG/CR-5485 (NRC 1998b) available in 2007.
- Maintenance unavailability data is based on the most recent Hope Creek operating experience up to the freeze date.

<u>HRA</u>

- Extensive HRA re-assessment is performed utilizing the EPRI HRA Calculator 4.0 based on operating crew interviews using the latest EOPs and support procedures. Significant input from simulator observations is also included to supplement the crew talk-through of procedures.
- Significant effort to examine dependencies among HEPs is included.
- Expansion of HRA pre-initiating events is included in the model.

<u>Thermal Hydraulic Modeling</u>

- MAAP 4.0.6 deterministic calculations are used to support the success criteria and HRA calculations (i.e., operator cues and time available for actions).
- Recirculation pump seal leakage failure modes are added to applicable scenarios.

<u>System Models</u>

- The analysis of FPS to support RPV makeup success has been added to the model.
- CST support of condensate injection is adequate when the makeup volume and flow rate requirements are small.

- Service water cross connect as an alternate water injection source to the RPV is included in the model.
- Extended DC battery life for cases with use of Portable Power supply has been assessed by PSEG and determined appropriate as a realistic approach to coping with an SBO.
- Shorter DC battery life for cases without successful DC charging from the Portable Power supply has been included in SBO accident sequence evaluations.

Accident Sequence Changes

- The accident sequence event trees were modified using the results of the latest MAAP calculations to assess success criteria.
- Addition of sequence specific success criteria for certain systems (e.g., CRD, HPCI, RCIC).

Internal Flood

- Internal Flood accident sequence evaluation has been developed and quantified consistent with the ASME PRA Standard and has been integrated into the full-power internal events model. Pipe failure data from EPRI evaluation of operating experience is the bases for the pipe failure probabilities.

Level 2

- The full spectrum of radionuclide release categories is included in the PRA model for Level 2. This will support SAMA evaluations as part of life extension initiatives.

Tracking of Model Changes for 2008 Update

- As part of the PRA update, URE changes and other significant changes were input separately and the model was recalculated to assess the resulting change impact on the CDF risk metric.

Changes that resulted in decreasing the CDF include the following:

- Seasonal success criteria for the SSW and SACS heat removal system
- Incorporation of HC.OP-AM.TSC-004 procedure to use the portable power supply for power to the DC chargers.
- Reassessment of HEPs using the latest interviews and HRA Calculation
- Changes in Basic Event Probabilities based on use of NUREG/CR-6928 latest generic date (Principally affecting EDG logic circuit failures)
- Incorporation of minor changes to flood impact logic in the system models
- Changes to SSW and DFP makeup logic within the long term response actions

- Changes to the initiating event frequencies to reflect recent industry and Hope Creek experience
- The evaluation of random and common cause data using plant specific and NRC updated data resulted in lower common cause failure probabilities. Specifically, the updated common cause failure probabilities using the latest INEEL updates to NUREG/CR-5497 are lower than those used in the 2003 model.
- The incorporation of a finer structure in the modeling of LOCAs by including location dependent LOCA contributors results in revised success criteria (less conservative) for some LOCAs.
- Improved success criteria using MAAP 4.0.6.
- Reductions in the transient initiating event frequencies based on incorporation of recent generic and Hope Creek operating experience.
- Added credit for use of CS from CST
- Added control of vent due to procedure change
- Reassessment of pre-initiator HEPs
- Reassessment of post-initiator HEPs

The HCGS PRA Update process includes an evaluation of the 2008 PRA model, data, and documentation using the ASME PRA Standard as endorsed by RG 1.200 (Rev. 1).

E.2.1.10 PRA MODEL HC108B UPDATE (PSEG 2008b)

As a result of the 2008 PRA Peer Review of HC108A PRA model and the PRA roll-out process, several refinements were identified, including a procedural change. These refinements are discussed below.

Changes in Risk Profile

The following is the integrated change in the CDF risk matrix from the 2005C model to this latest PRA model which is used for the SAMA evaluation (HC108B). The decrease in the CDF risk metric from 9.76E-6/yr (HC2005C) at 5E-11/yr truncation to 5.11E-06 (HC108B) at 1E-12/yr truncation is primarily due to:

- Seasonal success criteria for the SSW and SACS heat removal system
- Incorporation of HC.OP-AM.TSC-004 procedure to use the portable power supply for power to the DC chargers.
- Reassessment of HEPs using the latest interviews and HRA calculation results led to a reduction in the CDF of approximately 2E-6/yr
- Changes in Basic Event probabilities based on use of NUREG/CR-6928 latest generic data (Principally affecting EDG logic circuit failures)
- Incorporation of minor changes to flood impact logic in the system models
- Changes to SSW and DFP rev water makeup logic within the long term response actions
- The evaluation of random and common cause data using plant specific and NRC updated data resulted in lower common cause failure probabilities. Specifically, the updated common cause failure probabilities using the latest INEEL updates to NUREG/CR-5497 are lower than those used in the 2003 model.
- The incorporation of a finer structure in the modeling of LOCAs by including location dependent LOCA contributors results in revised success criteria (less conservative) for some LOCAs.
- Improved success criteria using MAAP 4.0.6.
- Changes to the generic initiating event frequencies
- Reductions in the transient initiating event frequencies based on incorporation of recent generic and Hope Creek operating experience.
- Added credit for use of CS from CST
- Added control of vent due to procedure change
- Reassessment of pre-initiator HEPs
- Reassessment of post-initiator HEPs
- Added procedure change to SSW/SACS to allow local manipulation of SSW to SACS heat exchangers under LOOP conditions
- Improved Inverter Room Cooling logic

Increases in CDF resulted from the following:

- The reassessment of internal floods including the inputs from design engineering, operations, and system managers, as well as the latest EPRI pipe failure rates and internal flooding analysis methodology.
- Removed SW injection to RPV for Level 1 because it is not proceduralized.
- Removed credit for Condensate Transfer as RPV injection source
- In addition, the HC108B model used the FTREX quantification engine which allowed efficient quantification at a lower truncation limit (i.e., 1E-12/yr).

E.2.2 CURRENT PRA MODEL OF RECORD

The Hope Creek PRA model of record (HC108B) was completed in December 2008. This revision is a result of the 2008 PRA Peer Review of HC108A and the roll-out process where several refinements were identified, including a procedural change. The SAMA analysis is based upon this PRA model. The changes incorporated into this model are discussed above. The risk insights from this model are discussed below.

E.2.2.1 HC108B RESULTS

The Hope Creek PRA is a systematic evaluation of plant risk utilizing the latest technology available for Probabilistic Risk Assessment (PRA). The Hope Creek PRA is classified as a full-power internal events PRA, meaning that severe accident sequences have been developed from internally initiated events, including internal floods.

A figure of merit commonly quoted in PRAs is core damage frequency (CDF). While this figure of merit does not entirely represent the value of the PRA, it is a widely used indicator. The core damage frequency (CDF) calculated in the Hope Creek 2008 PRA (HC108B) is 5.11E-6 per year (truncation at 1E-12 per year), a decrease from both the HC108A calculated value of 7.60E-6 per year (truncation at 5E-11 per year) and the 2005C calculated value of 9.76E-6 per year (truncation at 5E-11 per year).

The resulting CDF figure of merit is below the NRC's surrogate safety goal which indicates that Hope Creek poses no undue risk and is within the range of CDFs for other nuclear plants.

In addition to the evaluation of accident sequences that could lead to core damage, the Hope Creek PRA also includes the second risk metric specified in RG 1.174, an evaluation of the containment performance by examining the Large Early Release Frequency (LERF) associated with possible radionuclide releases. The large early release frequency (LERF) calculated in the Hope Creek HC108B PRA is 4.76E-07 per year, a decrease from the HC108A calculated value of 8.63E-7 per year. Both the HC108A and HC108B increases in LERF over the 2005C value of 2.59E-7 per year were due to the reassignment of specific Level 2 sequence end states from "No LERF" to "LERF" based on the latest MAAP 4.0.6 deterministic calculations of radionuclide release timing and release magnitude. In addition, the internal flood updated evaluation resulted in additional sequences that lead directly to LERF.

E.2.2.2 HOPE CREEK LEVEL 2 PRA MODEL (PSEG 2008c)

The SAMA analysis is based upon the Hope Creek Model of record (HC108B) developed in 2008. This revision includes a complete Level 2 analysis.

E.2.2.2.1 Containment Evaluation Process

Since the publication of WASH-1400 (NRC 1975) and the Individual Plant Examinations (IPE)[1], it has been recognized that there can be significant conservatisms in risk estimates if it is assumed that containment failure and subsequent radioactive release to the environment always occur given a core damage event. By considering the active and passive mitigating system functions that can be utilized even after a significant amount of core degradation occurs, end states can be identified in which the primary containment maintains its integrity and, thereby, prevents substantial environmental release of radionuclides.

In the Hope Creek Level 1 PRA, the plant systems (and challenges to those systems) are evaluated using event tree methodology to determine the frequency of end states that may induce a condition in which the core is degraded or the primary system

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(1) Developed in response to GL88-20.

integrity is challenged. These system event trees have evolved since the event tree development provided in WASH-1400.

In the Level 2 analysis, containment event trees (CETs) are developed to provide the link between the core damage end states of Level 1 associated with inadequate core cooling and the end states reflecting the mitigation of core damage and containment challenge, or the contribution to radionuclide release of varying magnitudes. The spectrum of radionuclide releases that could result from the core damage condition is then calculated for the postulated discrete end states of the CET. For example, the model considers the performance of the drywell sprays as an effective mitigating system in the assessment of radionuclide mitigation. The CETs describe the various potential radionuclide release paths to the environment and provide an estimate of their relative likelihoods. This process is, of course, an iterative one, requiring technical feedback between the systemic event trees, the CETs, and the plant response evaluation.

The purpose of containment event trees (CETs) is to provide estimates of the following: (1) the frequency of radionuclide releases; (2) the release magnitude; and (3) the release timing resulting from the Hope Creek Level 1 PSA. With this goal in mind, the following parameters are considered with regard to characterizing a release sequence:

- Radionuclide release and transport mechanisms
- Time of containment failure
- Containment failure mode
- Size of containment failure
- Location of containment failure
- Effect of harsh environment on the operation of key systems
- Effectiveness of suppression pool scrubbing
- Effectiveness of secondary containment filtering

The approach used to achieve these goals is similar to that used in the IDCOR program (IDCOR 1984) and the NUREG-1150 program (NRC 1990a). The CETs are developed as models of the approximate chronological progression of events describing plant behavior following the core damage end state defined in the output of the Level 1 system event trees.

The mechanics of the containment evaluation process are implemented in four major steps:

1. Identification of Severe Accident Types or Classes

    a. The first step is the identification of the spectrum of accidents that could challenge containment integrity or lead to a direct release of radionuclides.

       This also involves the identification of the timing of containment isolation/failure and core melt. For example, Class I accidents are those in which core melt has begun but the containment is intact; whereas, Class II accidents are characterized by containment failure or containment at extreme pressures but core melt has not necessarily begun. The analysis considers the full range of severe accidents that have been identified in past BWR PRAs and NUREG/CR-4920 (NRC 1988).

2. Identification of Severe Accident Progression Phenomena

    a. The next step is the identification of the important accident phenomena (i.e., radionuclide release mechanisms and degraded core or containment interactions) that affect release pathways to the environment, and examination of the plant specific containment integrity analyses available to support the envelope of successful containment states. A chronological representation of these phenomena in the containment event tree framework is developed focusing on the progression paths that could lead to a release or an arrested state. As input to the containment response evaluation, the Hope Creek PRA uses estimates of the ultimate pressure and temperature capability of the containment from a Hope Creek specific analysis.

3. CET Quantification

    a. A quantification of the various progression paths leading to a radionuclide release from containment or a successfully mitigated end state is performed. To support the event tree quantification, functional fault trees are developed. These fault trees provide a focused description of the major containment failure mechanisms as well as an aid in understanding the containment failure modes described in the CET. The models also realistically integrate the human and system responses. Operator recovery actions under severe accident conditions, as documented in the Hope Creek EOP/SAMGs, are included in the baseline quantification.

The quantification process considers the CET entry state (i.e., core damage end state), as defined by the Level 1 plant systems analysis because these affect the structure of the CET. Similar sequences are merged into an accident class and the sequences are transferred as inputs to the specific Level 2 CET which is structured specifically to treat the accident class sequences. The containment response to degraded core conditions (MAAP or equivalent calculations) and "separate effects" analysis (including the containment structural analyses) are combined and used as the technical bases for the quantification of phenomenological events, environmental conditions, or sequence boundary conditions.

4. Characterization of Radionuclide Release Bins

    a. A spectrum of radionuclide release end states is used to characterize the releases. This includes an end state referred to as "OK." The "OK" end states are those in which the containment remains intact except for leakage. The consequences can be expressed in terms of magnitude of source terms and other release characteristics that affect ex-plant consequences such as timing. The releases are estimated using plant specific MAAP calculations. The Hope Creek PSA takes into account the best estimate progression of a given severe accident. Representative sequences are chosen for deterministic calculations. Multiple sequences of different types are calculated to lead to similar release bins.

E.2.2.2.1.1 Specific Technical Items Performed to Support the Containment Evaluation Process

Sequence Grouping (Interface with the Level 1 PSA)

A vital task to the accurate quantitative assessment of containment capability is ensuring that the interface and dependencies between the Level 1 PSA evaluation and the containment evaluation are precisely defined. This is assured by requiring two approaches: (1) a unique containment evaluation for each type of core damage accident end state, and (2) the transfer of cutsets from Level 1 into Level 2 to ensure the dependencies are appropriately accounted for. Such a coupled evaluation allows the following types of information to be accurately transferred from the Level 1 study to the containment evaluation and accounted for explicitly in the Level 2 assessment:

- Front line and support system unavailability
- Reactor coolant system parameters
- System recovery actions

- Time available for additional recovery and mitigative actions
- Reactor power level
- Containment status

Containment Capability Evaluation

The primary containment capability to withstand severe accident pressures and temperatures is a required part of the Level 2 evaluation. Available plant specific technical data and methods allow the estimation of the as-built ultimate load carrying capabilities.

In addition to the failure probability and failure location, the size and timing of the failure are important considerations in the source term evaluation. In order to ascertain the size of potential pressure or temperature induced failures, the details of the containment design and construction are vital.

The plant specific information necessary to evaluate the containment capability to maintain its integrity during severe accident conditions included an assessment of the following:

- The structural capability of the containment at elevated pressures and temperatures
- The containment penetrations' ability to withstand high pressure and temperatures
- The ability of hatches and seals to withstand excessive pressure and temperature conditions including:
  - Drywell head seal
  - Personnel hatch
  - Equipment hatch
- The drywell head flange connection
- The air lock design
- The equipment hatch design
- The drywell to torus vent line penetrations and bellows assemblies
- The torus to reactor building vacuum breakers
- Containment response capabilities (i.e., structural, thermo-dynamic, and hydrodynamic) under a wide spectrum and variety of severe accidents scenarios
- The design of the torus as influenced by pool hydrodynamic loadings

- Various categories of drywell and torus penetration assembly design details and materials of construction
- Containment capabilities (both drywell and suppression pool) under partial or floodup conditions

These were investigated during the Hope Creek plant specific containment capability assessment.

<u>Scenario and Containment Event Tree Development</u>

Accident scenarios that progress to unacceptable end-states from the Level 1 PSA (i.e., degraded core conditions) have a number of operator action recovery steps and potential physical phenomena that need to be assessed to determine the eventual end state, i.e., safe stable state or a radionuclide release. The scenarios or pathways that lead to these states are defined through the use of a containment event tree.

The Containment Event Tree (CET) provides the framework that allows the evaluation of severe accident phenomena and accident management issues. The inputs to the CET are the accident sequences from the Level 1 PSA. The output from the CET is a set of radionuclide release categories.

The criteria for successful construction of the CET include the following:

- The CET structure is compatible with the type of Level 1 PSA accident challenge identified.
- The core melt progression time phases (i.e., in-vessel and ex-vessel accident progression) are explicitly treated in the CET.
- The functional CET nodes are selected to allow the user to describe phenomenological and system functional failure modes, evaluate accident management actions, and discriminate accident sequences according to radiological release magnitude and timing.
- The radionuclide release magnitude and timing for each accident sequence end state are unambiguously determinable from the identified sequences.
- The phenomenological process which dominates the release category assigned to an accident sequence can be traced.
- Success paths for recovery of degraded core conditions during in-vessel core melt progression accidents are explicitly modeled to facilitate the development of appropriate accident management strategies.

The containment event tree includes sufficient detail to quantify the effects of plant modifications and changes in emergency procedures and Severe Accident Mitigation Guidelines (SAMGs), yet is concise enough to allow effective communication of the assessment results.

The development and evaluation of the containment event tree requires establishing success criteria for the following:

- Containment integrity
- In-vessel core cooling
- Ex-vessel core cooling
- Radionuclide release magnitude/timing

These success criteria are derived from previous PSA work and plant specific MAAP deterministic code calculations in certain cases.

The containment event tree development includes an evaluation of the detailed interaction between systems, accident progression phenomena, and operating staff actions during the initial phases of a plant challenge associated with inventory control failures leading to the evaluation of core damage in-vessel and subsequent challenge to containment. The containment event tree includes an assessment of the ability to arrest core damage in-vessel. The starting point for the Level 2 analysis is a severe accident challenge coming from the Hope Creek Level 1 assessment. Therefore, the evaluation of containment response begins with significant plant failures and problems associated with such a sequence. The starting point for Level 2 sequences is the condition of core damage.

Therefore, the initial effort by the operating staff involves evaluating the ability to arrest the challenge before vessel breach. Subsequent efforts in the CET address operating staff actions to terminate core melt progression with the containment intact. This supports the accident management evaluation and the ability to credit systems normally not successful in avoiding core damage which may in the long term support termination of a severe accident. One of the most important aspects of the Hope Creek CET methodology for future accident management is the incorporation of the Severe

Accident Management Guidelines (SAMGs) into the structure of the CET, and the quantification of the CET. Therefore, extra effort has been included in the Hope Creek PSA to carefully factor in the latest SAMGs and an HRA evaluation of the directed actions.

For the Hope Creek Mark I BWR containment type, a CET structure was developed for each of the unique types of accident challenges. From previous BWR PRAs there have been approximately 12 different types of challenges identified. These challenges have resulted in three basic structural types of CETs. Therefore, the Hope Creek CETs consist of three structurally different CET types. These CET types are then used following the appropriate plant damage states and are quantified differently depending upon the plant damage state, i.e., the Level 1 output information using the system and cutsets and dependencies applicable to each sequence of events from Level 1 all the way through the Level 2.

Phenomenological Analysis and Containment Challenge Evaluation Response

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. Deterministic calculations are used to provide the following information:

- The pressures and temperatures in the RPV, the drywell, and the wetwell for various accident scenarios
- 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

The MAAP code is used to provide baseline estimates for plant responses, accident sequence timing, and radionuclide releases. All of these MAAP calculations are performed at the highest theoretical Extended Power Uprate (EPU) power level.

A critical insight for the Hope Creek containment is that RPV breach and subsequent core-coolant interactions do not by themselves result in containment overpressure/overtemperature failure within the "early" time phase if cooling is available to the debris.

Source Term Magnitude

CET outcomes that are expected to produce similar source terms (e.g., LERF) are binned into the same release category. Source term estimates are based on the Hope Creek MAAP calculations.

As part of the deterministic calculations, the radionuclide releases to the environment are determined. These releases are calculated by MAAP.

Quantification of Containment Event Trees (CET)

The CET quantification process extends the Level 1 models into the severe accident regime. Accident sequences from Level 1 with similar functional impacts are merged together into the appropriate accident classes and are transferred directly into the appropriate Level 2 CET. Each node in the CET is then evaluated using the fault tree models from the Level 1 analysis for the system or function as modified for any Level 2 limitations in timing, procedures, access, or dependencies. Therefore, when the CET is evaluated any equipment or operator failures that have already failed in the Level 1 sequence are automatically treated in the analysis, i.e., the dependencies are explicitly handled.

E.2.2.2.1.2 CET Overview

Hope Creek Containment Event Trees (CETs) are developed to provide the link between: (1) the Level 1 event tree core damage end states; and, (2) safe shutdown or radionuclide release end states that describe release magnitude and timing. The CET is used to map out the possible containment conditions affecting the radionuclide releases associated with a given core damage sequence. The portion of the spectrum of radionuclide releases which could result from the LERF end states is part of this calculation. These CETs describe the various potential radionuclide release paths to the environment and provide an estimate of their relative likelihoods. This process is, of course, iterative, and requires feedback and interactions among the analysts involved in the systemic event trees, the CET, and the plant response evaluation. The explicit link using the Level 1 sequence logic allows explicitly accounting for the dependencies between initiating events, system failures, and containment mitigation systems.

It has been recognized, since the publication of WASH-1400, that there can be a significant conservatism in the reactor plant risk estimates if the containment functionality is assumed to be ineffective following postulated core degradation or melt sequences. By considering the active and passive mitigating functions which can occur after a significant amount of core degradation, end states are likely in which the primary containment maintains its integrity or functionality. The containment event tree (CET) is a tool for identifying and analyzing the spectrum of accident scenarios which may evolve following postulated core damage accidents. CETs are developed and quantified in order to provide a realistic and systematic assessment of:

- The relative possibility of successfully mitigating postulated accidents
- The allocation of the severity and timing of associated radionuclide releases from a degraded core accident into LERF and non-LERF categories.

The containment event tree structure has been formulated to include the following objectives for the calculation of radionuclide release:

- To properly represent the time sequence of events and to divide the CET into major time periods
- To incorporate all important system, human and phenomenological occurrences including possible recovery
- To maintain a simplified representation
- To preserve the nature of the challenge throughout the analysis
- To explicitly recognize the effect of postulated containment failure modes

- To allow the identification of recovery and repair actions that can terminate or mitigate the progression of a severe accident (note that prevention measures have been addressed in the system evaluation of core damage frequency)
- To categorize the end states of the resulting sequences into groups that can be assessed for their effect on public safety

The first objective was achieved by representing the containment event tree as a series of occurrences based upon MAAP runs and NRC code results. Some compromise to time phasing occurs where two events are mutually dependent upon each other. However, the occurrence of mutually dependent events is minimized, and the event tree generally represents the chronological sequence of events from initiator to Level 2 end state.

A balance must be struck between the second and third objective to provide a comprehensive, but manageable analysis. Strict application of the second objective would cause the containment event tree to be very large, with numerous systems and actions represented. The third objective argues for simplified representation to achieve improved scrutibility and usefulness of the results. As pointed out in NUREG-1150 (NRC 1990a), it is more appropriate to use a streamlined CET, for the purposes of defining major phenomena of interest and illustrating potential mitigation measures. The streamlined CET, augmented by functional fault trees, is then believed most useful in clearly displaying important information.

In order to achieve a balance between these two principal objectives, the current analysis implements the containment event tree assessment in a time phased approach reflecting the approximate chronology of the severe accident scenarios:

- The first time phase involves occurrences up to vessel breach.
- The second time phase covers the period from vessel failure or arrest in-vessel until the intermediate term phenomena have occurred. This can be visualized as being approximately 3 to 15 hours after vessel challenge.
- The third time phase includes longer term phenomena such as containment heat removal response.

Naturally, these time phases may overlap given certain accident scenarios.

The remaining objectives were satisfied by using a sufficient number of top events and companion functional fault trees to describe qualitatively and quantitatively the systems, operator actions, phenomena, failure modes, and end states.

A set of deterministic and probabilistic analyses, and other plant information are needed as input to these models, including:

- Containment Structural Analyses
- SAMGs (Including Containment Control)
- Level 1 Analysis and Results
- Containment Walkdown Results
- P&IDs of Containment Control Systems
- Schematics of Containment Structure and Penetrations
- Technical Specifications
- Containment Leak Data
- Operating Experience
- Deterministic Model (e.g., MAAP).(1)

The CET allows a detailed characterization of the state of containment from the time of the initial core damage to either mitigation of the accident within the RPV or penetration of the RPV. The core melt progression sequences are also followed through their potential interaction with the containment to states involving either: (a) successful mitigation within the containment; or (b) a radionuclide release.

In the development of the CET, the important factors which affect the consequences for an accident are considered. Consequences in this context are measured in terms of the magnitude and timing of the radionuclide release. The primary focus of the back-end analyses is on containment failure mode and release timing rather than on source term analysis. The identification of the containment failure mode and timing is generally used

(1) The PSA utilizes the MAAP code for plant specific analyses of containment challenges and other reference plant calculations for additional support. However, industry experience and staff positions on phenomenological uncertainties are also taken into account.

as an indicator of the type of response that can either mitigate or reduce containment failure probability.

The CET structure includes event tree nodes that address the following aspects of severe accidents that are considered important for characterizing a radionuclide release:

- Core damage accident class (i.e., the entry state to the CET);
- Mitigating system response including operator actions (post core melt);
- Containment response, including pressures, temperatures and possibly failure location, path, and size, if appropriate.

Types of CETs

Several types of containment event trees are necessary to characterize various containment challenges. Three different containment event trees are used:

- CET1: Class I and III CET: Containment initially intact. These sequences are characterized by an initial loss of coolant makeup to the reactor vessel that leads to core damage. The attempts to arrest the melt progression in-vessel and ex-vessel are assessed along with containment integrity during the challenge. In all cases, the entry point to the containment event tree is at the time that the core is initially damaged.
- CET2: Class II and IV: Containment is initially failed or subject to incipient failure before core damage. For these classes of accidents, the primary containment boundary would generally fail before or at the time the molten core penetrates the reactor vessel. In Class II accident sequences, the inability to remove heat from the containment results in a gradual heat-up of the suppression pool. For Class IV accidents, the amount of energy transferred to the suppression pool exceeds its heat removal capacity.
- CET 3: Class V: CET3 is used to evaluate several distinct core melt scenarios: (1) LOCAs outside containment for which coolant makeup to the reactor vessel has failed leads to a core melt event with a direct release pathway from the vessel to the reactor building; and (2) an interfacing LOCA or drywell bypass.

Class I, II, III, IV and V CET Functional Nodes

The functional event nodes of the CET which can be considered in a detailed calculation are as follows:

- Containment Isolated (IS)

- RPV Depressurization (OP)
- Core Melt Arrested In-Vessel (RX)
- Combustible Gas Venting Initiated (GV)
- Containment Remains Intact (CZ)
- Injection Established to RPV or Drywell (SI)
- Containment Flooding Occurs with DW Vent (FC)
- Containment Heat Removal (HR)
- Containment Vent (VC)
- Suppression Pool Bypass (SP)
- No Large Containment Failure (NC)
- Inventory Make up Available (MU)
- Drywell Intact (DI)
- Wetwell Airspace Breach (WW)
- Reactor Building Effectiveness (RB)

The top level functional events analyzed in the Level 2 analysis are described in more detail below.

Containment Isolation (IS)

Containment isolation is the first nodal decision point of the CET. The "IS" node is used to assess whether the Hope Creek containment has been successfully isolated given the core damage challenge identified in the Level 1 PSA. As part of this assessment, it is noted that the containment is required to be inerted. In addition, the primary containment (drywell) pressure is maintained at a slightly higher pressure than the wetwell (~0.1psid). This operational aspect is used to limit the initial downcomer vent clearing loads on the torus. It has the side benefit of providing additional indication of the initial vacuum breaker positions prior to an event occurring. Specifically, an open vacuum breaker would not allow the differential pressure to be maintained. This increases the success probability that the vacuum breakers are initially closed, i.e., one of the potential failure modes is minimized.

The PSA examines in detail the status of the containment isolation systems prior to core melt. This node considers:

- The pathways that could significantly contribute to containment isolation failure
- The signals required to automatically isolate the penetration
- The potential for generating the signals for all initiating events
- Consideration of testing and maintenance
- The quantification of each containment isolation mode (including common-mode failure)

Initiating events and Level 1 sequences that include containment failure (i.e., Class II, IV) are transferred to CETs that bypass the IS node.

The IS node is failed by definition for containment bypass accidents (Class V). Containment bypass sequences involve those events that are initiated by a break in a pipe outside of the containment with the potential to release radionuclides directly from the RPV to secondary containment structures or to the environment. Analyses performed for other BWRs have shown that these types of scenarios result in large magnitude releases. The analyses have not taken credit for fission product retention within the system piping and retention in secondary containment buildings. Given this, Class V core damage events are modeled as leading directly to LERF.

Operator Depressurizes the Reactor Vessel (OP)

This heading represents the manual or automatic action of depressurizing the RPV. The operator recovery action to depressurize the reactor allows low pressure system injection to the RPV if the low pressure systems are operable. The upward path at this node represents successful depressurization and the down path models failure.

The status of RPV pressure can have a profound impact on the ability to successfully mitigate a severe accident and the subsequent containment response. Therefore, the determination of the RPV pressure is key to understanding subsequent active and passive mitigation capability.

Core Melt Progression Arrested In-vessel (RX)

This containment event tree node (RX) addresses the ability to arrest core melt progression within the reactor vessel. Specifically, success requires recovery of coolant makeup to the reactor vessel so that cooling may be reestablished to prevent further degradation of the fuel integrity. The time window for successful recovery of coolant inventory occurs between core melt initiation and the time when the core melt progression cannot be halted within the RPV. This can be one hour to several hours depending upon the sequence of events and the analytic model used. (The HCGS CET analysis allows 40 min. following core damage for actions to terminate core melt progression before RPV breach is inevitable).

The assessment addresses:

- The operator action to inject to the RPV
- The equipment availability
- Phenomena which may preclude successful arrest of the core melt progression in-vessel.

The makeup sources to ensure debris cooling in-vessel consist of the same sources examined in the Level 1 system evaluation. Note that "RX" success is also strongly dependent on the successful RPV depressurization at the previous node, (OP). In turn, RX also has strong influences on subsequent CET nodes such as "SI", availability of water injection to the containment after RPV breach. The "SI" node examines water recovery over a longer time frame.

Combustible Gas Venting (GV)

This node addresses the possibility that the containment may have a combustible gas mixture and no operator actions would be taken to mitigate the condition. The upward branch defines the path where the primary containment vent has been opened to control combustible gas mixtures resulting from severe accident progression, given the unlikely situation that the containment is deinerted. The downward path represents cases in which the containment remains inerted or the vent is not otherwise opened.

Early Containment Failure (CZ)

Energetic containment failure modes resulting from the core melt accident sequence initiator and the subsequent phenomenological events at the time of initial RPV breach due to debris attack are estimated to have potentially high radionuclide releases. These can also be considered early releases for Class I and III. (Exceptions may include delayed release for extended SBO event sequences.)

Event heading (CZ) describes the condition of the containment after a failure of the primary system. In the upward path, the containment has remained intact during the initial stages of core melt progression up through RPV breach and blowdown, while the downward path depicts an overpressure failure of the drywell induced near the time of the loss of primary system integrity.

The containment is the primary defense in retaining core melt fission products. The failure modes considered in the early containment failure mode include the following:

- Containment pressurization due to RPV blowdown causes rapid containment pressure rise above capability
- Steam explosion
- Recriticality
- Direct containment heating
- Hydrogen deflagration in a deinerted containment
- Combustible gas venting
- Drywell failure due to debris interaction with the concrete (see discussion under SI)

The structure of the CZ node is divided into in-vessel and ex-vessel phenomena, depending upon the success or failure of the RX node.

These items can potentially result in over-pressurizing the pedestal and drywell at the time of vessel breach. The radionuclide concentrations in the RPV and containment are high at the time of vessel breach and the flows out of the containment could be high. This means radionuclide releases have the potential to be high at this time. All of this results in minimal retention of radionuclides and the potential for large magnitude releases.

Wherever possible, the MAAP code is used for plant specific analyses of containment challenges. However, deterministic analyses regarding the capability of the Hope Creek containment to withstand the various energetic accident phenomena were not performed. Rather, industry studies and staff positions on phenomenological uncertainties were taken into account to assign failure probabilities that are deemed representative of a "generic" Mark I containment. An assessment of the Hope Creek containment capability in response to slower developing overtemperature and overpressure scenarios (e.g., loss of debris cooling, loss of containment heat removal) was performed and is documented in the Hope Creek MAAP Deterministic Calculations Notebook.

Ex-vessel steam explosions evaluated in CZ can be exacerbated by water availability into the drywell prior to RPV breach.

<u>Injection Established to RPV or Drywell (SI)</u>

The drywell floor is the location where a substantial fraction of the core debris may be deposited if core damage cannot be arrested in-vessel and the RPV is subsequently breached.

This node addresses whether adequate water is available to the drywell for debris coolability. This is contingent on equipment availability, an assessment of the phenomena of debris coolability and drywell integrity, and operator actions to initiate drywell sprays.

Subsequent to debris attack of the RPV, containment challenge may occur from direct debris interaction with the steel containment shell, high temperatures in the drywell, or a combination of high temperatures coupled with high pressures due to noncondensible gas generation. Injection of water into the containment and/or the RPV can mitigate the consequences of a core melt and prevent all of these failure modes. Each of these is discussed below:

Drywell Sprays

Drywell sprays can mitigate the consequences of a potential core melt accident. The sprays can perform at least three beneficial functions, the two most important of which are:

1. Scrubbing fission products that are not otherwise scrubbed (i.e., in the case where the suppression pool is bypassed); and
2. Providing water to cool the core debris on the drywell floor.[(1)]

A third function related to pressure control is useful and proceduralized but it is not explicitly quantified in the Level 2 except as implemented as part of RHR operation for suppression pool cooling.

Vessel Water Injection

RPV water injection can perform some of the same functions as spray operation mentioned above (i.e., scrub fission products from the debris), prevent containment overtemperature failure, and reduce the core concrete reaction by quenching the debris. The systems that might perform the function of coolant injection post core melt at Hope Creek include:

- Condensate
- Low pressure coolant injection
- Core spray
- Fire protection system
- SW cross tie

[(1)] The pedestal may contain debris. This debris is cooled by spray injected water that enters the pedestal through the pedestal doorway. In this mode of operation, containment failure could be prevented by termination of drywell wall heating and the associated temperature induced containment failure, and noncondensible gas generation due to core concrete reaction.

Operation of the vessel water injection systems after vessel failure will act to cool the core debris that remains on the drywell floor, cool the drywell atmosphere as a result of steam generation and cool the RPV internal structure (i.e., this cooling may prevent fission product revaporization from the RPV). The post-core melt water injection will prevent the drywell steel shell from failing due to debris contact and the drywell atmosphere from reaching very high temperatures and failing the drywell head seal. An added benefit for vessel water injection after vessel breach is the potential to scrub ex-vessel fission products via the water overburden.

Containment failure size and location is dependent on the status of this CET function.

Containment Flood (FC)

This node addresses the question of whether the procedures and operator actions will be taken to flood the containment with external water during the core melt progression, or whether the actions will be to maintain suppression pool level at approximately the LCO limits. The availability of an external injection water source, the instrumentation to monitor injection, and vent capability are all included.

Note that the Hope Creek SAGs restrict containment flooding if RPV is not breached and no LOCA has occurred, i.e., RPV pressure is greater than 50 psig above torus pressure.

Containment Heat Removal (HR)

This node would address the availability of the RHR system and the operator action to initiate the system for containment heat removal.

The Hope Creek Mark I containment system is provided with significant heat removal capacity and heat management capabilities. The management of heat in the containment prior to, during, and following a severe core damage event directly affects containment response. The Hope Creek containment heat capacity can be classified as both active and passive. The passive capacities include the suppression pool and the containment structure. The active heat management capabilities include the RHR system, the RWCU system, venting, and containment drywell coolers. This event tree node addresses all heat management capabilities, but the dominant influence on successful containment heat removal post core melt is the RHR system. (Note that containment venting is discussed separately below in the VC node.) Severe accident effects on the performance of the RHR system (e.g., steam binding) are considered in the model.

RWCU and drywell coolers have minimal heat removal capability and are not modeled in the PRA.

The RHR system, operating in the suppression pool cooling mode, can maintain long term containment integrity through adequate containment heat removal if other failure modes can also be mitigated. With the RHR system operating during the course of a core melt accident, containment pressure and temperature can be maintained within the structural failure criteria of the containment. As a result, the consequences of a radioactive release to the environment can be prevented.

The upward branch at this event tree node represents successful containment heat removal via the RHR system operating in the suppression pool cooling mode. The downward branch models failure of containment heat removal.

Containment Vent (VC)

This event heading characterizes use of the wetwell vent to relieve containment pressure. Venting provides the operator a means of removing decay heat and non-condensable gases, and maintaining the integrity of the containment. At this node, the upward path represents successful use of the vent, while the downward path represents venting failure due to mechanical faults, inadequate procedures, or operator error. Severe accident effects on the performance of the wetwell vent (e.g., high differential pressure prevents valve operation) are considered in the model.

Suppression Pool Bypass (SP)

This node is an assessment of hardware availability to preserve the suppression function of the torus and is addressed in the RB node.

If the operator is unsuccessful in maintaining the heat management functions as described in the preceding section, wetwell venting would be required to maintain containment integrity. The issue is applicable to both containment venting and containment failure scenarios. This event heading examines the potential for suppression pool bypass that would allow the release of radionuclides from the reactor vessel to pass directly out of containment without the benefit of suppression pool scrubbing during venting. The upward branch at this event tree node represents no bypass, while the downward branch models suppression pool bypass.

No Large Containment Failure (NC)

This CET node probabilistically distinguishes between containment failure modes that may result in small or large containment failure modes.

In some cases the size of the failure is determined by the accident progression, e.g., unmitigated ATWS and the NC model is a “pass-through.”

Continued Inventory Makeup (MU)

This node considers the effect of harsh environment (e.g., humidity, temperature) following containment failure or venting on the availability and survivability of injection systems and components.

Containment Response Integrity (DI, WW)

The containment failure location and its size will impact the calculated radionuclide releases. Failure location and size also depend on the core melt accident sequence and the operability of mitigating systems. Section 3 of PSEG 2008 provides additional detail on the derivation of these failure mode locations, and discusses the basis for estimating the size of containment breach. The containment analysis presented in

Section 3 (PSEG 2008c) meets the ASME PRA Standard requirement that plant-specific containment analyses be performed. The analysis considers the effects of high temperatures and pressures on seals, valves, hatches, and other key areas of the containment structure (e.g., drywell head area). When studies of reference plants were used, their applicability to Hope Creek was taken into consideration and explicitly discussed.

Reactor Building Effectiveness (RB)

This node is an assessment of the active and passive features of the secondary containment, along with phenomena that may cause bypass of the secondary containment, that contribute to scrubbing radionuclide releases in the building.

Contributors to the determination of reactor building effectiveness include the following:

- Reactor Building integrity after containment failure,
- Filtration, Recirculation and Ventilation System (FRVS) operation,
- Fire sprinkler operation (water curtains),
- Hydrogen combustion in the reactor building, and
- Reactor building integrity after hydrogen combustion.

The down branch of the Reactor Building node implies minimal effectiveness of the Reactor Building to retain fission products due to primarily two failure mechanisms:

1. Combustion of gases in the reactor building causing high temperature and minimum or zero retention.
2. Direct pathway from the containment failure location to the blowout panels with minimal interaction within the reactor building.

The potential issues that influence the determination of Reactor Building effectiveness are the strong dependence of the radionuclide residence time in the Reactor Building on the following events or features of the secondary containment:

- The mode of containment failure,
- The location of containment failure relative to the reactor building point of failure,
- The location of any water flooding in or into the reactor building,

- The rate of gas production in the primary containment,
- The status of FRVS,
- The status of the railroad doors or other reactor building paths, and
- The potential for delayed[(1)] hydrogen burning in the reactor building that leads to a deflagration.

During LOCA outside containment scenarios resulting in core damage, the fission products released from a breach of the RCS and the containment may bypass the containment and be carried by gas flows from the primary system into adjacent buildings and possible to the environment. In such an event, one of the main concerns would be the plant's ability to retain fission products during transport of the fission products through the secondary structure.

It must be noted that Reactor Building responses to fission product releases from the primary system are not solely dependent on one particular plant feature or characteristic; instead, the fission product retention characteristics of the Reactor Building depends on the combination of various plant specific features and characteristics.

E.2.2.2.1.3 Release Categories

The spectrum of possible radionuclide release scenarios is represented by a discrete set of categories or bins based in part on the discussion in Section 5.1 of the 2008 Level II analysis (PSEG 2008c). The end states of the containment event sequences may be characterized according to certain key quantitative attributes that affect offsite consequences. These attributes include two important factors:

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

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(1) It is noted that MAAP burns the hydrogen discharged to the Reactor Building at the lowest combustion point on the combustion curve, thus precluding deflagration event calculations in the MAAP analysis.

Therefore, the containment event tree end states represent the source term magnitude and relative timing of the radionuclide release using a discrete set of end states. As described in Section 5.1 of the 2008 Level II analysis, the number of end state categories to be used in the source term characterization offers a level of discrimination similar to that included in numerous published PRAs.

One of the bins or radionuclide release categories is allocated to address the risk metric of Large Early Release Frequency (LERF).

Large Early Release is defined in the ASME PRA Standard (ASME 2002 and ASME 2005) as follows:

> *The rapid, unmitigated release of airborne fission products from the containment to the environment occurring before the effective implementation of off-site emergency response and protective actions such that there is a potential for early health effects.*

Regulatory Guide 1.174 (NRC 2002) states the following:

> *LERF is being used as a surrogate for the early fatality QHO. It is defined as the frequency of those accidents leading to significant, unmitigated releases from containment in a time frame prior to effective evacuation of the close-in population such that there is a potential for early health effects.*

There are a number of issues regarding the definition of CET end states that are summarized below:

- NUREG-1150 (NRC 1990a) analyses and other BWR PRAs have shown that the public risk can be correlated with radionuclide release bins characterized by:
  - Magnitude of radionuclide release
  - Time of radionuclide release
  - Location and energy of the release
- For LERF end states, the magnitude of the release must be sufficient to cause early fatalities. A summary of the relationship of the Cesium and Iodine release fractions versus their potential for impacting early fatalities is presented in Section 5.4.2 of the 2008 Level 2 NB (PSEG 2008c).

The description of the source term, the release timing, and the implications of each are determined using the results of MAAP calculations. Past PRA evaluations are used for comparison purposes to ensure that the MAAP calculations demonstrate the correct trends. In addition, the information developed in previous studies has been used in making subjective assessments for these source term characterizations. The event sequences contributing to a radionuclide release are ranked on the basis of the product of the relative consequences (based on estimated radionuclide release fractions of noble gases, CsI, and Te) and their respective conditional probabilities, so that potentially risk-dominant scenarios are identified and adequately represented. Those that are similar in timing and release fractions are sorted into groups of release categories to reduce the number of release categories required to calculate the risk profile.

The next section identifies the criteria used to define the release bins used in the Hope Creek Level 2 PSA Analysis.

CRITERIA USED IN TIMING AND RELEASE MAGNITUDE ASSIGNMENTS

The release categories are defined based on two parameters: timing and severity (i.e., release magnitude). Timing of the release for each sequence is based on MAAP calculations of the sequence chronology. The classification of release magnitude is based on review of industry studies.

Timing Bins

Appendix E of the 2008 Level 2 NB (PSEG 2008c) provides a discussion of MAAP results and their implications regarding the timing of a declaration of a General Emergency – indicating the potential for population protective actions including evacuation. In Section 5.4.1.1 of the Level 2 NB (PSEG 2008c), the Hope Creek specific evacuation studies are presented that indicate that the worst case evacuation time for the EPZ is 4 hours.

Three timing categories are used, as follows:

1. Early (E) - Less than 4 hours from declaration of a General Emergency[(1)],[(2)]
2. Intermediate (I) - Greater than or equal to 4 hours, but less than 24 hours from declaration of a General Emergency
3. Late (L) - Greater than or equal to 24 hours from declaration of a General Emergency

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

- 0-4 hours is conservatively assumed to include cases in which minimal offsite protective measures have been observed to be performed in non-nuclear accidents.
- 4-24 hours is a time frame in which much of the offsite nuclear plant protective measures can be assured to be accomplished.
- >24 hours are times at which the offsite measures can be assumed to be fully effective.

The General Emergency Action Level is used as the trigger for interaction.

The declaration of a General Emergency is used in this analysis to set the initial time of the clock to initiate the public protective actions. Therefore, the times cited here for the determination of radionuclide release bins are relative to the declaration of a General Emergency. This declaration is sequence dependent. See Appendix E of the Level 2 NB (PSEG 2008c) for a further discussion of this determination for Hope Creek.

<u>Evacuation Timing</u>

The evacuation time for Hope Creek Generating Station has been evaluated by KLD Associates (KLD 2004). The results of the study indicate that under the most adverse conditions evaluated, the required evacuation time is 4 hours. The evacuation time for the most restrictive segment under the worst postulated conditions is 4 hours. This means that if 4 hours warning can be given prior to the release, evacuation can be considered successfully implemented (this may be conservative).

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(1) The cue for General Emergency is set by the Emergency Action Levels (EALs).

(2) The time for evacuation sets the time allowed for determination of an “Early” release. This definition is based on the worst case evacuation time. See HCGS E-Plan and KLD evacuation study which are discussed in Appendix E of this report.

Release Magnitude Bins

The five severity classifications associated with volatile or particulate releases[(1)] are defined as follows:

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

RELEASE SEVERITY	FRACTION OF RELEASE CSI FISSION PRODUCTS
High	greater than 10%
Medium/Moderate	1 to 10%
Low	.1 to 1.0%
Low-Low(1)	less than 0.1%
Negligible	much less than 0.1%

This relationship allows the use of results of many consequence analyses in providing source terms from the breadth of release paths analyzed in this study. Understanding the plant specific influences on each sequence source term as affected by the various release paths allows the assignment of release severity to each of the sequences. Plant specific deterministic calculations are also available for accident sequences that

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(1) The effects of noble gases may be quite dramatic, causing substantial early health effects if released early in an accident and if the associated plume is directed at an occupied location. The noble gases themselves may result in early injuries or fatalities. However, in most sequences the release of noble gases may occur over a relatively extended period of time unless an energetic failure of containment or secondary containment occurs. Therefore, the noble gases are implicitly included in the definition of release categories. There may however be situations in which noble gases alone result in early health effects, those cases are considered of low probability. The focus of the release categories is on the dominant term in cost benefit evaluations from past assessments, i.e., the latent health effects for which the above formulation adequately encompasses the effects of noble gases on the release.

provide the other species of radionuclide releases that can cause different health effects.

Because timing can be an important parameter in assessing accident management and emergency response actions, the timing of the release is carried along with the end state definition.

See Table E.2-3 for a summary of the release severity and timing classification scheme.

E.2.2.2.1.4 Summary of Results

The containment event tree end states are characterized using a two-term matrix (i.e., severity and timing) as shown in Table E.2-3.

E.2.2.3 PRA MODEL OF RECORD SUMMARY (PSEG 2008c)

The Hope Creek PRA is a systematic evaluation of plant risk utilizing the latest technology available for Probabilistic Risk Assessment (PRA). The Hope Creek PRA is classified as a full-power internal events PRA meaning that severe accident sequences have been developed from internally initiated events, including internal floods.

A figure of merit commonly quoted in PRAs is core damage frequency (CDF). While this figure of merit does not entirely represent the value of the PRA, it is a widely used indicator. The core damage frequency (CDF) calculated in the Hope Creek 2008 PRA (HC108B) is 5.11E-6 per year (at a truncation of 1E-12 per year), a decrease from both the HC108A calculated value of 7.6E-6 per year and the 2005C calculated value of 9.76E-6 per year.

The resulting CDF figure of merit is below the NRC's surrogate safety goal which indicates that Hope Creek poses no undue risk and is within the range of CDFs for other nuclear plants.

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(1) This category includes some venting sequences where only the noble gases are released.

In addition to the evaluation of accident sequences that could lead to core damage, the Hope Creek PRA also includes the second risk metric specified in RG 1.174, an evaluation of the containment performance by examining the Large Early Release Frequency (LERF) associated with possible radionuclide releases. The large early release frequency (LERF) calculated in the Hope Creek HC108B PRA is 4.76E-07 per year, an increase from the 2005C calculated value of 2.59E-7 per year. The increase in LERF is primarily due to the reassignment of specific Level 2 sequence end states from “No LERF” to “LERF” based on the latest MAAP 4.0.6 deterministic calculations of radionuclide release timing and release magnitude. In addition, the internal flood updated evaluation resulted in additional sequences that lead directly to LERF.

The decrease in the CDF risk metric from 9.76E-6/yr (HC2005C) at 5E-11/yr truncation to 5.11E-06/yr (HC108B) at a 1E-12/yr truncation is primarily due to the incorporation of the following changes into the PRA model:

- Seasonal success criteria for the SSW and SACS heat removal system
- Incorporation of HC.OP-AM.TSC-004 procedure to use the portable power supply for power to the DC chargers.
- Reassessment of HEPs using the latest interviews and HRA Calculation Results led to a reduction in the CDF of approximately 2E-6/yr
- Changes in Basic Event Probabilities based on use of NUREG/CR-6928 latest generic date (Principally affecting EDG logic circuit failures)
- Incorporation of minor changes to flood impact logic in the system models
- Changes to SSW and DFP makeup logic within the long term response actions
- The evaluation of random and common cause data using plant specific and NRC updated data resulted in lower common cause failure probabilities. Specifically, the updated common cause failure probabilities using the latest INEEL updates to NUREG/CR-5497 are lower than those used in the 2003 model.
- The incorporation of a finer structure in the modeling of LOCAs by including location dependent LOCA contributors results in revised success criteria (less conservative) for some LOCAs.
- Improved success criteria using MAAP 4.0.6.
- Changes to the generic initiating event frequencies
- Reductions in the transient initiating event frequencies based on incorporation of recent generic and Hope Creek operating experience.

- Added credit for use of CS from CST
- Added control of vent due to procedure change
- Reassessment of pre-initiator HEPs
- Reassessment of post-initiator HEPs
- Added procedure change to SSW/SACS to allow local manipulation of SSW to SACS heat exchangers under LOOP conditions
  - Improved Inverter Room Cooling logic

Increases in CDF resulted from the following:

- The reassessment of internal floods including the inputs from design engineering, operations, and system managers, as well as the latest EPRI pipe failure rates and internal flooding analysis methodology.
- Modified SW injection to RPV for Level 1 because it is not proceduralized.
- Removed credit for Condensate Transfer as RPV injection source

As can be seen from Figure E.2-1, the top four initiating events contributing to CDF for Hope Creek are loss of offsite power, loss of service water, manual shutdown, and turbine trip. See Table E.2-5 for a complete list of the top initiating event contributors to CDF.

Figure E.2-2 provides a chart of the LERF contributions by initiating event. The top four initiating events contributing to LERF are ISLOCA initiators associated with ECCS discharge paths, turbine trip, loss of offsite power, and loss of service water. See Table E.2-2 for specific LERF contributions listed by initiating event. Table E.2-4 provides a summary of the CET release bins and frequencies.

E.2.3 PRA PEER REVIEW OF THE HC108A MODEL

Because of the significant changes in PRA methods (e.g., HRA, Internal Flooding, Common Cause, LOOP treatment, and Level 2), a complete PRA Peer Review of the Hope Creek PRA model (HC108A) was requested by PSEG. The PRA Peer Review was performed in October 2008 using the ASME PRA Standard (ASME 2005) as endorsed by the NRC in Reg. Guide 1.200, Rev. 1, as well as use of the NEI process (NEI 2007).

The PRA Peer Review process confirmed the adequacy of the Hope Creek PRA model for use in PRA applications based on both the exit interview and the Draft PRA Peer Review Report.

The PRA Peer Review using the ASME PRA Standard resulted in the identification of some minor numerical changes to basic events and several additions to model logic. These are identified above under Section 2.1.12. These changes led to a requantification of the Hope Creek PRA model resulting in the HC108B model which is the model used for the SAMA evaluation. Also, the HC108B model used the FTREX quantification engine, which allowed more efficient quantification at a lower truncation limit, i.e., 1E-12/yr in order to meet MSPI convergence criteria.

E.2.3.1 SUPPORTING REQUIREMENTS ASSESSMENT

The ASME PRA Standard has 331 individual Supporting Requirements; 301 Supporting Requirements are applicable to the Hope Creek PRA. Thirty (30) of the ASME PRA Standard Supporting Requirements are not applicable to Hope Creek (e.g., PWR related, multi-unit related). Of the 301 ASME PRA Standard Supporting Requirements applicable to Hope Creek, based on the draft PRA Peer Review report on HC108A more than 90% are supportive of Capability Category II or greater. Refer to the summary in the below table.

ASME PRA Standard	**Hope Creek Assessment**	
Capability Category	# of SRs	%
Not Met	8	2.7%
I	7	2.3%
I/II	13	4.3%
II	35	11.6%
II/III	22	7.3%
III	9	3.0%
Met (All)	207	68.8%
TOTAL:	**301**	**100%**

Findings were resolved in the update from HC108A to HC108B. The SRs delineated as ‘Not Met’ in the above table were addressed in the HC108B model so as not to impact the SAMA analysis. Any SRs that were not met would not (numerically) impact the results of this SAMA analysis.

E.3 LEVEL 3 RISK ANALYSIS

This section addresses the critical input parameters and analysis of the Level 3 portion of the risk assessment. In addition, Section E.7.3 summarizes a series of sensitivity evaluations to potentially critical parameters.

E.3.1 ANALYSIS

The MACCS2 code (NRC 1998a) was used to perform the Level 3 probabilistic risk assessment (PRA) for Hope Creek Generating Station (HCGS). The input parameters given with the MACCS2 "Sample Problem A," formed the basis for the present analysis. These generic values were supplemented with parameters specific to HCGS and the surrounding area. Site-specific data included population distribution, economic parameters, and meteorological data. Generic economic parameters for the costs of evacuation, relocation and decontamination were escalated from the time of their formulation (1986) to more recent (April 2008) costs. Plant-specific release data included release frequencies and the time-dependent distribution of nuclide releases from 11 accident sequences at HCGS. The behavior of the population during a release (evacuation parameters) was based on plant and site-specific set points (i.e., declaration of a General Emergency) and evacuation time estimates (KLD 2004). These data were used in combination with site specific meteorology to calculate risk impacts (exposure and economic) to the surrounding (within 50 miles) population.

E.3.2 POPULATION

The population surrounding the HCGS site is estimated for the year 2046.

The population distribution projection was based on census data available via SECPOP2000 (NRC 2003). The baseline population was determined for each of 160 sectors, consisting of sixteen directions (i.e., N, NNE, NE,…NNW) for each of ten concentric distance rings with outer radii at 1, 2, 3, 4, 5, 10, 20, 30, 40 and 50 miles surrounding the site. SECPOP2000 census data from 1990 and 2000 were used to determine a ten year population growth factor for each of the concentric rings. The ten year population growth factor for each ring was applied successively and uniformly to all sectors in the ring to calculate the 2046 population distribution.

The total year 2046 population for the 160 sectors in the region is estimated at 6,634,468. The distribution of the population is given for the 10-mile radius and the 50-mile radius from HCGS in Tables E.3-1 and E.3-2, respectively.

E.3.3 ECONOMY

MACCS2 requires certain agricultural based economic data (fraction of land devoted to farming, annual farm sales, fraction of farm sales resulting from dairy production, and property value of farm and non-farm land) for each of the 160 sectors. This data can be generated by SECPOP2000 (NRC 2003), but due to recent errors discovered with the economic parameter processing of the SECPOP2000 code, SECPOP2000 was not utilized to develop the economic parameters for the HCGS analysis. Instead, the economic parameters were developed manually using data in the 2002 National Census of Agriculture (USDA 2004) and from the Bureau of Economic Analysis (BEA 2008) for each of the 23 counties surrounding the plant, to a distance of 50 miles. The values used for each of the 160 sectors were the data from each of the surrounding counties multiplied by the fraction of that county’s area that lies within that sector. Region-wide wealth data (i.e., farm wealth and non-farm wealth) were based on county-weighted averages for the region within 50-miles of the site using data in the 2002 National Census of Agriculture (USDA 2004) and the Bureau of Economic Analysis (BEA 2008). The portion of each county within 50-miles of the site was accounted for in the calculation.

In addition, generic economic data that is applied to the region as a whole were revised from the MACCS2 sample problem input in order to account for cost escalation since 1986, the year that input was first specified. A factor of 1.96, representing cost escalation from 1986 to April 2008 using the consumer price index was applied to parameters describing cost of evacuating and relocating people, land decontamination, and property condemnation

MACCS2 economic parameters utilized in the HCGS analysis include the following:

HCGS MACCS2 ECONOMIC PARAMETERS

VARIABLE	DESCRIPTION	HCGS VALUE
DPRATE(1)	Property depreciation rate (per yr)	0.20
DSRATE(2)	Investment rate of return (per yr)	0.07
EVACST(3)	Daily cost for a person who has been evacuated ($/person-day)	52.92
POPCST(3)	Population relocation cost ($/person)	9799
RELCST(3)	Daily cost for a person who is relocated ($/person-day)	52.92
CDFRM0(3)	Cost of farm decontamination for various levels of decontamination ($/hectare)	1102 2450
CDNFRM(3)	Cost of non-farm decontamination per resident person for various levels of decontamination ($/person)	5880 15679
DLBCST(3)	Average cost of decontamination labor ($/man-year)	68595
VALWF0(4)	Value of farm wealth ($/hectare)	16636
VALWNF(4)	Value of non-farm wealth ($/person)	275924

(1) DPRATE uses NUREG/CR-4551 value (NRC 1990b).
(2) DSRATE based on NUREG/BR-0058 (NRC 2004).
(3) These parameters for HCGS use the NUREG/CR-4551 values (NRC 1990b), updated to April 2008 using the consumer price index. For CDFRM0 and CDNFRM, two values are utilized, one for each of two levels of modeled decontamination (i.e., dose reduction factors of 3 and 15).
(4) VALWF0 and VALWNF are based on 2002 National Agriculture Census (USDA 2004) and Bureau of Economic Analysis data (BEA 2008), updated to the April 2008 using the consumer price index.

E.3.4 FOOD AND AGRICULTURE

Food ingestion is modeled using the new MACCS2 ingestion pathway model COMIDA2 (NRC 1998a), consistent with Sample Problem A. The COMIDA2 model utilizes national based food production parameters derived from the annual food consumption of an average individual such that site specific food production values are not utilized. The fraction of population dose due to food ingestion is typically small compared to other population dose sources. For HCGS, less than one percent of the total population dose is due to food ingestion.

E.3.5 NUCLIDE RELEASE

The core inventory at the time of the accident is based on a plant specific calculation (PSEG 2006b). The core inventory corresponds to the end-of-cycle values for HCGS operating at 3917 MWt, 2 percent above the current (EPU) licensed value of 3,840

MWt. Table E.3-3 summarizes the estimated HCGS core inventory used in the MACCS2 analysis.

HCGS nuclide release categories, as determined by the MAAP computer code, are related to the MACCS2 categories as shown in Table E.3-4. Releases were modeled as occurring at the top of the reactor building (61 meters). The thermal content of each of the releases was assumed to be the same as ambient, i.e., buoyant plume rise was not modeled. Each of these assumptions was considered in sensitivity analyses, presented in Section E.7.3.

Release frequencies, nuclide release fractions (of the core inventory), shown in Table E.3-6, and the time distribution of the release were analyzed to determine the sum of the exposure (50-mile dose) and economic (50-mile economic costs) risks from 11 accident sequences (also given in Table E.3-6). Each accident sequence was chosen to represent a set of similar accidents. Representative MAAP cases for each of the release categories were chosen based on a review of the Level 2 model cutsets and the dominant types of scenarios that contributed to the results. A brief description of each of those MAAP cases is provided in Table E.3-5, and a summary of the release magnitude and timing for those cases is provided in Table E.3-6. Multiple release duration periods (i.e., plume segments) were defined which represent the time distribution of each category's releases.

E.3.6 EVACUATION

Reactor trip for each sequence was taken as time zero relative to the core containment response times. A General Emergency (GE) is declared when plant conditions degrade to the point where it is judged that there is a credible risk to the public. For the HCGS analysis the time of the GE declaration was estimated based on the HCGS emergency action levels (PSEG 2007). The declaration times are presented in Table E.3-6.

The MACCS2 User's Guide input parameters of 95 percent of the population within 10 miles of the plant (Emergency Planning Zone, EPZ) evacuating and 5 percent not evacuating were employed. These values are conservative relative to the NUREG-

1150 study, which assumed evacuation of 99.5 percent of the population within the EPZ (NRC 1990a).

The evacuees are assumed to begin evacuation 65 minutes after a general emergency has been declared at a base evacuation radial speed of 2.8 m/sec. This time to begin evacuation and the base speed is derived from the site specific evacuation study (KLD 2004). The evacuation speed is a time-weighted average value accounting for season, day of week, time of day, and weather conditions. It is noted that the longest evacuation time presented in the study (i.e., full 10 mile EPZ, winter snow conditions, 99^{th} percentile evacuation) is 4 hours (from the issuance of the advisory to evacuate). The evacuation parameters were considered further in the sensitivity analyses presented in Section E.7.3.

E.3.7 METEOROLOGY

Annual hourly meteorology HCGS data sets from 2004 through 2007 were investigated for use in MACCS2. Of the hourly data of interest (10-meter wind speed, 10-meter wind direction, multi-level temperatures used to calculate stability class, and precipitation), less than 1% of the data were missing for 2004, and less than 4% for 2005 and 2007. Approximately 8.3 % of year 2006 precipitation data was missing. Traditionally, up to 10% of missing data is considered acceptable. MACCS2 requires complete sequential hourly data, therefore missing data must be estimated. Data gaps were filled by (in order of preference): using data from the backup met pole instruments (10-meter), using corresponding data from another level of the main met tower, interpolation (if the data gap was less than 6 hours), or using data from the same hour and a nearby day (substitution technique). The 10-meter wind speed and direction were combined with precipitation and atmospheric stability (derived from the vertical temperature gradient) to create the hourly data file for use by MACCS2.

The 2004 data set was found to result (see Section E.7.3 for discussion of sensitivity analysis) in the larger economic cost risk and dose risk compared to the 2005, 2006, and 2007 data sets. Given that the 2004 data set was the most complete and resulted in the largest risk results of interest, the 2004 hourly meteorology was selected as the base case.

Atmospheric mixing heights were specified for AM and PM hours for each season of the year. These values ranged from 600 meters to 1700 meters. (EPA 1972)

E.3.8 MACCS2 RESULTS

Table E.3-7 shows the mean off-site doses and economic impacts to the region within 50 miles of HCGS for each of 11 release categories calculated using MACCS2. The mean off-site dose impacts are multiplied by the annual frequency for each release category and then summed to obtain the dose-risk and offsite economic cost-risk (OECR) for each unit. Table E.3-7 provides these results.

E.4 BASELINE RISK MONETIZATION

This section explains how HCGS calculated the monetized value of the status quo (i.e., accident consequences without SAMA implementation). HCGS also used this analysis to establish the maximum benefit that could be achieved if all on-line HCGS risk were eliminated, which is referred to as the Maximum Averted Cost-Risk (MACR). The internal events CDF of 4.44E-06 (at a truncation of 5E-11/yr) was used for the calculations in the following sections. External risk is addressed in Section E.4.6.2.

E.4.1 OFF-SITE EXPOSURE COST

The baseline annual off-site exposure risk was converted to dollars using the NRC's conversion factor of $2,000 per person-rem, and discounted to present value using NRC standard formula (NRC 1997):

$$W_{pha} = C \times Z_{pha}$$

Where:

W_{pha} = monetary value of public health accident risk after discounting

C = $[1-\exp(-rt_f)]/r$

t_f = years remaining until end of facility life = 20 years

r = real discount rate (as fraction) = 0.03 per year

Z_{pha} = monetary value of public health (accident) risk per year before discounting ($ per year)

The Level 3 analysis showed an annual off-site population dose risk of 22.86 person-rem. The calculated value for C using 20 years and a 3 percent discount rate is approximately 15.04. Therefore, calculating the discounted monetary equivalent of accident dose-risk involves multiplying the dose (person-rem per year) by $2,000 and by the C value (15.04). The calculated off-site exposure cost is $687,646.

E.4.2 OFF-SITE ECONOMIC COST RISK

The Level 3 analysis showed an annual off-site economic risk of $155,055. Calculated values for off-site economic costs caused by severe accidents must be discounted to present value as well. This is performed in the same manner as for public health risks and uses the same C value. The resulting value is $2,331,969.

E.4.3 ON-SITE EXPOSURE COST RISK

Occupational health was evaluated using the NRC recommended methodology that involves separately evaluating immediate and long-term doses (NRC 1997).

For immediate dose, the NRC recommends using the following equation:

Equation 1:

$$W_{IO} = R\{(FD_{IO})_S - (FD_{IO})_A\}\{[1 - \exp(-rt_f)]/r\}$$

Where:

W_{IO} = monetary value of accident risk avoided due to immediate doses, after discounting

R = monetary equivalent of unit dose ($2,000 per person-rem)

F = accident frequency (events per year) (4.44E-06 (total CDF)) at 5E-11/yr truncation

D_{IO} = immediate occupational dose [3,300 person-rem per accident (NRC estimate)]

$_S$ = subscript denoting status quo (current conditions)

$_A$ = subscript denoting after implementation of proposed action

r = real discount rate (0.03 per year)

t_f = years remaining until end of facility life (20 years).

Assuming F_A is zero, the best estimate of the immediate dose cost is:

$$W_{IO} = R\,(FD_{IO})_S\{[1 - \exp(-rt_f)]/r\}$$

$$= 2{,}000 * 4.44E\text{-}06 * 3{,}300 * \{[1 - \exp(-0.03 * 20)]/0.03\}$$

= $441

For long-term dose, the NRC recommends using the following equation:

Equation 2:

$$W_{LTO} = R\{(FD_{LTO})_S - (FD_{LTO})_A\} \{[1 - \exp(-rt_f)]/r\}\{[1 - \exp(-rm)]/rm\}$$

Where:

W_{LTO} = monetary value of accident risk avoided long-term doses, after discounting, $

D_{LTO} = long-term dose [20,000 person-rem per accident (NRC estimate)]

m = years over which long-term doses accrue (as long as 10 years)

Using values defined for immediate dose and assuming F_A is zero, the best estimate of the long-term dose is:

$$W_{LTO} = R\,(FD_{LTO})_S \{[1 - \exp(-rt_f)]/r\} \{[1 - \exp(-rm)]/rm\}$$

$$= 2{,}000 * 4.44E\text{-}06 * 20{,}000 * \{[1 - \exp(-0.03*10)]/0.03\} \{[1 - \exp(-0.03*10)]/0.03*10\}$$

= $2308

The total occupational exposure is then calculated by combining Equations 1 and 2 above. The total accident related on-site (occupational) exposure risk (W_O) is:

W_O = $W_{IO} + W_{LTO}$ = ($441+$2,308) = $2,749 person-rem

E.4.4 ON-SITE CLEANUP AND DECONTAMINATION COST

The total undiscounted cost of a single event in constant year dollars (C_{CD}) that NRC provides for cleanup and decontamination is $1.5 billion (NRC 1997). The net present value of a single event is calculated as follows. NRC uses the following equation to integrate the net present value over the average number of remaining service years:

$$PV_{CD} = [C_{CD}/mr][1-\exp(-rm)]$$

Where:

PV_{CD} = net present value of a single event

C_{CD} = total undiscounted cost for a single accident in constant dollar years

r = real discount rate (0.03)

m = years required to return site to a pre-accident state

The resulting net present value of a single event is $1.3E+09. The NRC uses the following equation to integrate the net present value over the average number of remaining service years:

$$U_{CD} = [PV_{CD}/r][1-\exp(-rt_f)]$$

Where:

PV_{CD} = net present value of a single event ($1.3E+09)

r = real discount rate (0.03)

t_f = 20 years (license renewal period)

The resulting net present value of cleanup integrated over the license renewal term, $1.95E+10, must be multiplied by the total CDF (4.44E-06) to determine the expected value of cleanup and decontamination costs. The resulting monetary equivalent is $86,567.

E.4.5 REPLACEMENT POWER COST

Long-term replacement power costs were determined following the NRC methodology in NRC 1997. The net present value of replacement power for a single event, PV_{RP}, was determined using the following equation:

$$PV_{RP} = [\$1.2\times10^{8}/r] * [1 - \exp(-rt_f)]^2$$

Where:

PV_{RP} = net present value of replacement power for a single event, ($)

r = 0.03

t_f = 20 years (license renewal period)

To attain a summation of the single-event costs over the entire license renewal period, the following equation is used:

$$U_{RP} = [PV_{RP} / r] * [1 - \exp(-rt_f)]^2$$

Where:

U_{RP} = net present value of replacement power over life of facility ($-year)

After applying a correction factor to account for Hope Creek's size relative to the "generic" reactor described in NUREG/BR-0184 (NRC 1997) (i.e., 1287 megawatt electric / 910 megawatt electric, the replacement power costs are determined to be 7.81E+09 ($-year). Multiplying 7.81E+09 ($-year) by the CDF (4.44E-06) results in a replacement power cost of $34,709.

E.4.6 MAXIMUM AVERTED COST-RISK

The HCGS MACR is the total averted cost-risk if all internal and external events risk associated with on-line operation were eliminated. This is calculated by summing the following components:

- Maximum Internal Events Averted Cost-Risk
- Maximum External Events Averted Cost-Risk

As described in Section E.5.1, the MACR is used in the SAMA identification process to determine the depth of the importance list review. In addition, the MACR is used in the Phase I analysis as a means of screening SAMAs. The following subsections provide a description of how each of these components is calculated and used together to obtain the HCGS MACR.

E.4.6.1 INTERNAL EVENTS MAXIMUM AVERTED COST-RISK

The maximum internal events averted cost-risk is the sum of the contributors calculated in Sections E.4.1 through E.4.5:

Maximum Averted Internal Events Cost-Risk

Off-site exposure cost	$687,646
Off-site economic cost	$2,331,969
On-site exposure cost	$2,749
On-site cleanup cost	$86,567
Replacement power cost	$34,709
Total cost	$3,143,640

This total represents the monetary equivalent of the risk that could be eliminated if all risk associated with on-line internal event hazards (including internal floods) could be eliminated for HCGS. The internal events MACR is rounded to next highest thousand ($3,144,000) for SAMA calculations. It should be noted that the Phase II cost benefit calculations account for the difference between the rounded MACR and the actual MACR by adding the difference to the averted cost-risk calculated for each SAMA.

E.4.6.2 EXTERNAL EVENTS MAXIMUM AVERTED COST-RISK

The maximum averted cost-risk for external events must be quantified for the cost benefit calculations; however, this cost-risk must be estimated based on information in the IPEEE given that complete, current, quantifiable external events models are not available. As described in Sections E.5.1.5 and E.5.1.6, some changes have been made to these models, but they have not been updated to reflect recent plant changes or the full spectrum of current PRA techniques. Therefore, the absolute CDF values that are included in the IPEEE would generally not be considered to be directly comparable to the results of the internal events PRA model. However, the fire model, which is the largest and dominant external event contributor for HCGS, was updated in the year 2003 to reflect more current initiating event frequencies and suppression failure probabilities (among other changes) (PSEG 2003). Generally, these are the areas that are considered to have the largest potential influence on fire CDF apart from the underlying PRA model. Given that HCGS has already adjusted the PRA to reflect these types of changes, supporting a reduced fire CDF for other reasons would be beyond the scope of the SAMA analysis. As a result, the external events CDFs are used directly in the MACR calculation.

The method chosen to account for external events contributions in the SAMA analysis is to use a multiplier on the internal events results. This is simply the ratio of total CDF (including internal and external) to only internal CDF. The internal events CDF is represented by the sum of the Level 2 release category frequencies at a truncation of 5E-11. This ratio is called the External Events multiplier and its value is calculated as follows:

EE Multiplier = (4.44E-06+2.35E-05) / (4.44E-06) = 6.3

The contributions of the external events initiators are summarized in the following table:

IPEEE CONTRIBUTOR SUMMARY EXTERNAL EVENT INITIATOR GROUP CDF

Fire*	1.74E-05
Seismic	1.12E-06
High Winds	1.00E-06
Transportation & Nearby Facility**	1.00E-06
External Flooding	1.00E-06
Detritus***	1.00E-06
Chemical Release	1.00E-06
Total EE CDF	2.35E-05

* HCGS 2003 External Events PRA (PSEG 2003)
** The CDF for accidental aircraft impact was estimated to be 6.7E-8/yr in the HCGS UFSAR, Revision 7, December 29, 1995.
*** Detritus CDF from IPEEE ranged from 5.2E-7 to 9.2E-7.

The lack of detailed quantitative analyses makes it difficult to establish a meaningful CDF for many of these initiator groups; however, some assumptions can be made about the non-quantified initiator groups that could be used to further develop a total external events CDF.

The HCGS IPEEE methodology implies that if the plant licensing bases are met, the plant and facilities design meets the 1975 Standard Review Plan (SRP) criteria, and the site walkdown does not reveal any potential vulnerabilities not already considered in the design basis analysis, then the CDF posed by an initiator is less than the 1.0E-06 per yr screening criterion.

E.4.6.3 HCGS MAXIMUM AVERTED COST-RISK

As stated in Section E.4.6, the MACR is the total of these two components:

Internal Events = $3,144,000

External Events = $16,663,200

Maximum Averted Cost-Risk = $19,807,200

E.5 PHASE 1 SAMA ANALYSIS

The Phase 1 SAMA analysis, as discussed in Section E.1, includes the development of the initial SAMA list and a coarse screening process. This screening process eliminated those candidates that are not applicable to the plant's design or are too expensive to be cost beneficial even if the risk of on-line operations were completely eliminated. The following subsections provide additional details of the Phase 1 process.

E.5.1 SAMA IDENTIFICATION

The initial list of SAMA candidates for HCGS was developed from a combination of resources. These include the following:

- HCGS PRA results and PRA Group Insights
- Industry Phase 2 SAMAs (review of the potentially cost effective Phase 2 SAMAs for selected plants)
- HCGS Individual Plant Examination IPE (HCGS IPE) (PSEG 1994a)
- HCGS IPEEE (PSEG 1997)

These resources are judged to provide a list of potential plant changes that are most likely to reduce risk in a cost-effective manner for HCGS.

In addition to the "Industry Phase 2 SAMA" review identified above, an industry based SAMA list was used in a different way to aid in the development of the HCGS plant specific SAMA list. While the industry Phase 2 SAMA review cited above was used to identify SAMAs that might have been overlooked in the development of the HCGS SAMA list due to PRA modeling issues, a generic SAMA list was used to help identify the types of changes that could be used to address the areas of concern identified through the HCGS importance list review. For example, if instrument air availability was determined to be an important issue for HCGS, the industry list would be reviewed to determine if a plant enhancement had already been conceived that would address HCGS's needs. If an appropriate SAMA was found to exist, it would be used in the HCGS list to address the Instrument Air issue; otherwise, a new SAMA would be developed that would meet the site's needs. This generic list was compiled as part of the development of multiple industry SAMA analyses and is available in NEI 05-01 (NEI 2005).

It should be noted that the process used to identify HCGS SAMA candidates focuses on plant specific characteristics and is intended to address only those issues important to the site. In this case, the existing capabilities of the plant preclude the need to include many of the potential SAMAs that have been identified for other BWRs. As a result, the types of changes that might be cost effective for HCGS are reduced and the SAMA list is relatively short.

E.5.1.1 LEVEL 1 HCGS IMPORTANCE LIST REVIEW

The HCGS PRA was used to generate a list of events sorted according to their risk reduction worth (RRW) values. The top events in this list are those events that would provide the greatest reduction in the HCGS CDF if the failure probability were set to zero. The events were initially reviewed down to an RRW of 1.01, which corresponds to about 1 percent reduction in the CDF given 100 percent reliability of the event. If the dose-risk and offsite economic cost-risk were also assumed to be reduced by a factor of 1.01, the corresponding averted cost-risk would be about $200,000, which also accounts for the impact of External Events after applying a factor of 6.3. Assuming that the minimum implementation cost (associated with a procedure change) is about $100,000, the Level 1 and 2 events were further reviewed down to a RRW of 1.006 to capture those events with potential averted costs down to $100,000. This review revealed these events were already addressed by previously identified SAMAs, or were identified as part of low probability scenarios, e.g., failure to scram, such that no feasible cost-beneficial SAMAs could be identified.

Table E.5-1 documents the disposition of each event in the Level 1 HCGS RRW list greater than or equal to an RRW of 1.006. Note that no basic events were preemptively screened from the process even if they solely represent sequence flags. Whatever the event, the intent of the process is to determine if insights can be gleaned to reduce the risk of the accident evolutions represented by the events listed. However, unique SAMAs are not identified for all of the events in the RRW list. Previously identified

SAMAs are suggested as mitigating enhancements when those SAMAs (or similarly related changes) would reduce the RRW importance of the identified event. It is recognized that in some cases, additional requirements may need to be imposed on the SAMA to get a reduction in the RRW value for the basic event listed. In these cases, if an existing SAMA can approximate such an impact, then it is considered to address the relevant event and provide a first order indication of the potential benefit. If warranted, a more detailed PRA analysis may then be required to provide a better estimate of the actual potential cost-benefit.

E.5.1.2 LEVEL 2 HCGS IMPORTANCE LIST REVIEW

A review of cutsets representing LERF was conducted to determine if any potential SAMA candidates were feasible. The review included those events with a Risk Reduction Worth (RRW) greater than or equal to 1.006 with respect to Level 2 release categories. Table E.5-2 lists those events and corresponding comments. The HCGS PRA model used to generate Level 1 cutsets also contained information regarding the containment status and Level 2 accident phenomena.

A review of cutsets from all non-intact release categories was made to determine if any dominant basic events or components that had not been identified in the Level 1 review should also be included in the Phase 1 SAMA list. As a result, most items that were dominant contributors to these Release Categories had already been identified in the Level 1 CDF review. If any new events that were considered important (RRW ≥ 1.006) for these Release Categories that were not previously identified would be added to the Phase 1 list in Table E.5-3.

E.5.1.3 INDUSTRY SAMA REVIEW

The SAMA identification process for HCGS is primarily based on the PRA importance listings, the IPE, and the IPEEE. In addition to these plant-specific sources, selected industry SAMA submittals were reviewed to identify any Phase II SAMAs that were determined to be potentially cost beneficial at other plants. These SAMAs were further analyzed and included in the HCGS SAMA list if they were considered to address potential risks not identified by the HCGS importance list review.

While many of the industry SAMAs reviewed are ultimately shown not to be cost beneficial, some are close contenders and a small number have been estimated to be cost beneficial at other plants. Use of the HCGS importance ranking should identify the types of changes that would most likely be cost beneficial for HCGS, but review of selected industry Phase II SAMAs may capture potentially important changes not identified for HCGS due to PRA modeling differences or SAMAs that represent alternate methods of addressing risk. Given this potential, it was considered prudent to include a review of selected industry Phase II SAMAs in the HCGS SAMA identification process.

Phase II SAMAs from the following United States nuclear power sites have been reviewed:

- Susquehanna Steam Electric Station (PPL 2006)
- Peach Bottom Atomic Power Station (EXELON 2001)
- James A. Fitzpatrick Nuclear Power Plant (ENTERGY 2008)
- Cooper Nuclear Station (NPPD 2008)
- DAEC (FPL 2008)
- Wolf Creek (WNOC 2006)

One Westinghouse PWR and five General Electric BWR sites were chosen from available documentation to serve as the potential Phase II SAMA sources. Many of the industry Phase II SAMAs were already represented by other SAMAs in the HCGS list, were known not to impact important plant systems or be relevant to the HCGS design, or were judged not to have the potential to be close contenders for HCGS. As a result, they were not added to the HCGS SAMA list. Those unique SAMAs that were considered to have the potential to be cost effective for HCGS were added to the list. The cost effective SAMAs for each of the sites identified above are reviewed in the following subsections.

E.5.1.3.1 Susquehanna Steam Electric Station

REVIEW OF SSES COST BENEFICIAL SAMAS

INDUSTRY SITE SAMA ID	SAMA DESCRIPTION	DISCUSSION FOR HCGS	DISPOSITION FOR HCGS SAMA LIST
2a	Improve Cross-Tie Capability Between 4kV AC Emergency Buses (A-D, B-C)	SSES did not credit cross-tie between EDG trains and relied on the swing EDG to mitigate EDG failures. For HCGS, this type of enhancement was identified based on the plant specific PRA results review (SAMA 5).	Already included
6	Procure Spare 480V AC Portable Station Generator	HCGS already has a portable generator that can be used to power the station battery chargers. The operator action to align the generator dominates the hardware failure probability and an additional generator would provide limited benefit. HCGS already includes a SAMA to automate alignment of the portable generator.	Already implemented
2b	Improve Cross-Tie Capability Between 4kV AC Emergency Buses (A-BC-D)	This SAMA is an enhancement over SSES SAMA 2a and allows cross-tie between any EDG division. All cross-tie options will be reviewed for HCGS as part of HCGS SAMA 5.	Already included.
3	Proceduralize Staggered RPV Depressurization When Fire Protection System Injection is the Only Available Makeup Source	This SAMA is specific to the SSES site and is based on the need to split flow from a single injection system between units. It is not applicable to the HCGS design.	Not included.
5	Auto Align 480V AC Portable Station Generator	Auto start and alignment of the 480V generator reduces the human error contribution and dependence issues related to providing alternate power. This is addressed by HCGS SAMA 5.	Already included.

E.5.1.3.2 Peach Bottom Atomic Power Station

REVIEW OF PBAPS COST BENEFICIAL SAMAS

INDUSTRY SITE SAMA ID	SAMA DESCRIPTION	DISCUSSION FOR HCGS	DISPOSITION FOR HCGS SAMA LIST
Phase II SAMA 21	INSTALL SUPPRESSION POOL JOCKEY PUMP FOR ALTERNATE INJECTION TO THE RPV	Peach Bottom proposed the suppression pool jockey pump as a means of improving the reliability of long term, independent injection to the RPV given the complexity of the alignment for the fire water injection method. This type of injection is generally required in loss of containment heat removal cases, but this did not include SBO cases given that it was a low pressure system and would require DC power to maintain the SRVs open. For these types of long term cases, operator reliability is not an issue for HCGS. In addition, the Condensate Storage and Transfer System is available as an injection option and the alignment of this system is not complex. Providing a suppression pool jockey pump similar to the one proposed by Peach Bottom would provide no measurable benefit.	Not included.

E.5.1.3.3 Fitzpatrick

REVIEW OF FITZPATRICK COST BENEFICIAL SAMAS

INDUSTRY SITE SAMA ID	SAMA DESCRIPTION	DISCUSSION FOR HCGS	DISPOSITION FOR HCGS SAMA LIST
Phase II SAMAs 26, 27, 30, 34, 36, and 61	Multiple Methods to Improve Battery Depletion	Fitzpatrick performed an evaluation of the benefit of improving SBO coping capabilities, primarily through extending the time DC power would be available. HCGS recently installed a portable 480V AC generator to accomplish the task of powering the batter chargers and operator reliability is now the limiting issue for the site with respect to providing alternate DC power. HCGS SAMA 5 addresses loss of offsite power issues and the Fitzpatrick SAMAs would not be beneficial to HCGS.	Already implemented/ included.

REVIEW OF FITZPATRICK COST BENEFICIAL SAMAS

INDUSTRY SITE SAMA ID	SAMA DESCRIPTION	DISCUSSION FOR HCGS	DISPOSITION FOR HCGS SAMA LIST
62	Develop a procedure to open the door of EDG buildings upon the high temperature alarm	This SAMA was developed to provide an alternate method of room cooling for the EDG rooms. HCGS has redundant sets of room cooling trains for each of the 4 EDG rooms. The SACS system normally supplies cooling water to the room coolers from the same division, but each cooler has a cross-tie to the other SACS division that can be aligned, if required. EDG room cooling issues were not identified on the importance list and are small contributors to HCGS risk.	Not included.

E.5.1.3.4 Cooper Nuclear Station

REVIEW OF COOPER NUCLEAR STATION COST BENEFICIAL SAMAS

INDUSTRY SITE SAMA ID	SAMA DESCRIPTION	DISCUSSION FOR HCGS	DISPOSITION FOR HCGS SAMA LIST
14	Portable generator for DC power to supply the individual panels.	This SAMA was designed to allow HPCI operation after battery depletion. HCGS already has a portable generator to perform this task.	Already implemented
25	Revise procedure to allow bypass of RCIC turbine exhaust pressure trip	Allows RCIC to operate when suppression pool pressures are high enough to trip the RCIC turbine on high turbine exhaust pressure. This failure mode is not explicitly developed for HCGS and could be examined further.	Added to SAMA list (SAMA I2)

REVIEW OF COOPER NUCLEAR STATION COST BENEFICIAL SAMAS

INDUSTRY SITE SAMA ID	SAMA DESCRIPTION	DISCUSSION FOR HCGS	DISPOSITION FOR HCGS SAMA LIST
78	Improve training on alternate injection via FPS	The intent of this SAMA is to improve the reliability of the operator action to align alternate injection with the fire protection system, but the SAMA does not identify what problems exist with the current training program, what credible changes could be made to measurably improve reliability, or how any such changes would impact the HRA assessment. The HCGS EOPs direct the use of fire water injection, which is then implemented using system level procedures. The action to align fire water injection has a reasonable low failure rate, an RRW value of 1.006, and a RAW value that is below 1.1. Any SAMAs implemented to improve the reliability of alternate injection with FPS would have a limited impact of risk. Further, it is possible that improved training could increase the operators' proficiency with FPS injection, but current HRA methodologies would estimate little, if any, reduction in the action's HEP based on improved training alone. As a result, no SAMAs are suggested.	Not included
30	Revise procedures to allow manual alignment of the fire water system to RHR heat exchangers	This SAMA was designed to mitigate loss of SW cooling to the RHR heat exchangers. Loss of cooling to the RHR heat exchangers can occur due to an important failure to open the intermediate cooling system's (SACS) heat exchanger valve, but this is an operator action and any additional action to supply alternate cooling to the RHR heat exchangers would be highly or completely dependent on the action to open the SACS heat exchanger valve. For hardware or support system failures that fail SACS, even if cooling water could be supplied to the RHR heat exchangers, the RHR pumps depend on SACS for room cooling (A&B) and lube oil cooling (A, B, C, D) so the availability of water to the HXs is irrelevant. As a result, additional hardware modifications would provide minimal benefit and are not suggested. Other SACS failures are of much lower importance and the inter-division SACS cross-tie is not even credited in the model.	Not included

REVIEW OF COOPER NUCLEAR STATION COST BENEFICIAL SAMAS

INDUSTRY SITE SAMA ID	SAMA DESCRIPTION	DISCUSSION FOR HCGS	DISPOSITION FOR HCGS SAMA LIST
68	Proceduralize the ability to cross connect the circulating water pumps and the service water going to the TEC heat exchangers	This SAMA is designed to provide an alternate cooling medium to the closed loop cooling system that cools the turbine building loads. For HCGS, the Station Service Water system ultimately provides cooling to the turbine building closed loop cooling system. Station Service Water does not have existing cross-ties to other systems, so a procedure change is not relevant to HCGS. SAMA 10 (use of B.5.b pump for alt injection) provides a lower cost means of maintaining long term injection after a failure of Service Water cooling.	Not included. Not applicable to HCGS.
33	Create ability for emergency connection of existing or new water sources to feedwater and condensate systems.	This SAMA appears to be aimed at providing a long term supply of water to FW/Condensate. At HCGS, the CST is aligned to the hotwell via a gravity feed mechanism and loss of FW/Condensate due to CST depletion is not a large contributor. LOCA cases can lead to depletion of the CST, but the only LOCA scenario above the RRW review threshold for HCGS is an ISLOCA scenario that leads to a high pressure core melt after successful ASD inhibit. SAMA 1 addresses the elimination of the guidance to use inhibit ADS, which would allow low pressure ECCS to function and provide makeup for 96 percent of the ISLOCA contribution. This is considered to be a lower cost, more appropriate change for HCGS.	Not included. Addressed by a lower cost SAMA.
40	Operator procedure revisions to provide additional space cooling to the EDG room via the use of portable equipment	Addressed in discussion for Fitzpatrick Phase II SAMA 62.	Refer to Fitzpatrick Phase II SAMA 62
45	Provide an alternate means of supplying the instrument air header	This SAMA is intended to improve the reliability of the Instrument Air system by providing an alternate supply to the system header. For HCGS, the Instrument Air system is not an important risk contributor and this type of enhancement is not required.	Not included
64	Proceduralize the use of a fire pumper truck to pressurize the fire water system	Fire water reliability can be enhanced by proceduralizing the use of a fire truck to pressurize the fire water header. HCGS already has this proceduralized.	Already implemented

REVIEW OF COOPER NUCLEAR STATION COST BENEFICIAL SAMAS

INDUSTRY SITE SAMA ID	SAMA DESCRIPTION	DISCUSSION FOR HCGS	DISPOSITION FOR HCGS SAMA LIST
75	Generation Risk Assessment implementation into plant activities	The intent of this SAMA appears to be the incorporation of risk management tools into work planning practices. This is already performed at HCGS.	Already implemented
79	Modify procedures to allow use of the RHRSW system without a SWBP	Not applicable to HCGS; the Service water system already operates without booster pumps for system cooling.	Not included. Not applicable to HCGS

E.5.1.3.5 Duane Arnold Energy Center

REVIEW OF DUANE ARNOLD ENERGY CENTER COST BENEFICIAL SAMAS

INDUSTRY SITE SAMA ID	SAMA DESCRIPTION	DISCUSSION FOR HCGS	DISPOSITION FOR HCGS SAMA LIST
156	Provide an alternate source of water for the RHRSW/ESW pit.	This SAMA addresses clogging of flow to the RHRSW/ESW pump intake area. This was addressed at DAEC by assuming that a cross connect could be added to allow communication between the Circ Water and RHRSW/ESW pits. HCGS has individual intake bays for each SW pump with lateral connections between each of the bays to allow cross flow in the event that one or more of the intakes becomes clogged.	Already implemented
166	Increase the reliability of the low pressure ECCS RPV low pressure permissive circuitry. Install manual bypass of low pressure permissive	The intent of this SAMA is to reduce the probability that low pressure injection will be failed by the low pressure permissive sensors or logic. This equipment is modeled for HCGS, but is a relatively low contributor. However, adding a key lock bypass would improve the reliability of a bypass action in the event of an interlock failure.	Added to SAMA list (SAMA I3)

E.5.1.3.6 Wolf Creek Generating Station

REVIEW OF WOLF CREEK GENERATING STATION COST BENEFICIAL SAMAS

INDUSTRY SITE SAMA ID	SAMA DESCRIPTION	DISCUSSION FOR HCGS	DISPOSITION FOR HCGS SAMA LIST
2	Modify the Controls and Operating Procedures for Sharpe Station to Allow for Rapid Response	This is a site specific SAMA that was developed to allow the Wolf Creek operators to control a local diesel generating station from the Wolf Creek main control room. This SAMA is not applicable to HCGS.	Not included
4 (case 2)	Update emergency procedures to direct local, manual closure of the RHR EJHV8809A and EJHV8809B valves if they fail to close remotely	This SAMA was developed to address questions about the ability of MOVs to close against the differential pressure in a specific ISLOCA sequence for Wolf Creek. This has not been identified as an important contributor for HCGS.	Not included
5	Enhance procedures to direct operators to open EDG Room doors for alternate room cooling	Addressed in discussion for Fitzpatrick Phase II SAMA 62.	Refer to Fitzpatrick Phase II SAMA 62
1	Permanent, Dedicated Generator for the NCP with Local Operation of TD AFW After 125V Battery Depletion	This was designed to assist in an SBO that included a seal LOCA. The design includes provisions to provide high pressure, primary side makeup and is a PWR specific issue. Also, HCGS already has a portable generator to address SBO issues.	Not included
3	AC Cross-tie Capability	This SAMA is designed to improve AC crosstie capability. For HCGS, this type of enhancement was identified based on the plant specific PRA results review (SAMA 5).	Already included
13	Alternate Fuel Oil Tank with Gravity Feed Capability	For Wolf Creek, fuel oil failures contributed significantly to the CDF and an alternate method to transfer fuel to the EDG day tank was determined to be cost effective. The diesel fuel oil system is modeled for HCGS, but the relevant failure events are below the review threshold and no cost beneficial changes would result from EDG fuel oil enhancements.	Not included
14	Permanent, Dedicated Generator for the NCP, one Motor Driven AFW Pump, and a Battery Charger	This was designed to assist in an SBO that included a seal LOCA. The design includes provisions to provide high pressure, primary side makeup and is a PWR specific issue. Also, HCGS already had a portable generator to address SBO issues.	Not included

E.5.1.3.7 Industry SAMA Identification Summary

The important issues for HCGS are generally considered to be addressed by the SAMAs developed through the PRA importance list review. The plant changes suggested as part of that review were developed to meet the specific needs of the plant such that those SAMAs are more likely to provide effective means of risk reduction than SAMAs taken from other sites. However, effort was made to review other industry SAMA analyses to determine if other sites identified plant changes that could be cost beneficial for HCGS based on modeling differences or other factors. For HCGS, the following additional SAMA candidates were identified based on a review of selected industry analyses:

- Develop a procedure to open the door of EDG buildings upon the high temperature alarm (SAMA I1)
- Revise procedure to allow bypass of RCIC turbine exhaust pressure trip (SAMA I2)
- Increase the reliability of the low pressure ECCS RPV low pressure permissive circuitry. Install manual bypass of low pressure permissive. (SAMA I3)

E.5.1.4 HCGS IPE PLANT IMPROVEMENT REVIEW

The HCGS IPE generated a list of risk-based insights and potential plant improvements. Typically, changes identified in the IPE process are implemented and closed out; however, there are some items that are not completed within the industry due to high projected costs or other criteria. Because the criteria for implementation of a SAMA may be different than what was used in the post-IPE decision-making process, these recommended improvements are re-examined in this analysis.

As a result of the IPE three potential improvements were identified for consideration; however, two of the changes were technically not plant improvements, but improvements to calculations that would allow more credit to be taken for existing plant features. These types of changes do not directly impact plant risk, but they can be used to aid in the management of plant risk and are considered as potential SAMAs. The following table summarizes the status of these improvements:

STATUS OF IPE PLANT ENHANCEMENTS

DESCRIPTION OF POTENTIAL ENHANCEMENT	STATUS OF IMPLEMENTATION	DISPOSITION
Perform further neutronics calculations to demonstrate that reactivity control is possible with a single division of SLC.	Implemented	The current PRA model credits a single SLC pump for providing reactivity control and preventing HCTL depressurization. No further review required.
Perform calculations to show that each SSW/SACS loop can operate with only one pump and that loop cross-tie is a viable recovery mechanism for the systems.	Implemented	Plant calculations have been performed to show that a single SACS pump, SSW-SACS heat exchanger, and SSWS pump can be successful under certain conditions, but not under all conditions. SSWS is operated with the cross-ties open so that either system can provide cooling to the RACS loads, but credit is not taken for one division of SSWS to cool the opposite division's SACS loads. Further analysis could potentially provide a basis for crediting the cross-division cooling of t he SACS loads by SSWS, but this would not result in any actual risk reduction given that the SSWS cross-ties are normally open. No further review required.
Develop operating procedures for the SACS in severe accident conditions.	Implemented	No further review required.

All of the plant changes suggested in the IPE have been implemented at HCGS and no further review of these items is required.

E.5.1.5 HCGS IPEEE PLANT IMPROVEMENT REVIEW

Similar to the IPE, any proposed plant changes that were previously rejected based on non-SAMA criteria should be re-examined as part of this analysis. In addition, any issues that are in the process of being resolved should be examined because their resolutions could be important to the disposition of some SAMAs. The IPEEE was used to identify these items.

The following table summarizes the status of the potential plant enhancements resulting from the IPEEE processes and their treatment in the SAMA analysis.

STATUS OF IPEEE PLANT ENHANCEMENTS

DESCRIPTION OF POTENTIAL ENHANCEMENT	STATUS OF IMPLEMENTATION	DISPOSITION
Install a missile shield in front of the Technical Support Center HVAC room (Room 5619, Door 19).	Implemented	No further review required.
Preclude unauthorized shipment and storage of explosives on the Delaware River.	Implemented	No further review required.

While the shipping practices on the Delaware River are not controlled by PSEG, the U.S. Coast Guard stopped explosive shipment and storage near the HCGS site and did not see any need for explosive shipment or storage along the river in the near future. Based on discussions with HCGS security personnel confirming the exclusion zone restrictions are still in place at the site, and have been enhanced in some cases, all of the plant changes suggested in the IPEEE are considered to have been implemented and no further review of these items is required.

An effort was also made to use the IPEEE to develop new SAMAs based on a review of the original results. However, the HCGS IPEEE was not maintained as a "living" analysis. This limits the capability of the models that make up the IPEEE as they do not include the latest PRA practices nor do they necessarily represent the current plant configuration or operating characteristics. The fact that the models cannot be "quantified" presents further difficulty because the results are limited to what has been retained from the original analysis. These factors limit the qualitative insights and quantitative estimates that can be made with regard to external events contributors. Therefore, the external events models are considered to be useful tools for identifying important accident sequences and mitigating equipment, but any quantitative results should not be directly combined with those from the internal events models due to the differences in the modeling characteristics. In the enclosed SAMA analysis, external event contributions are estimated for the reasons described above.

E.5.1.6 POST IPEEE SITE CHANGES

In addition to performing a review of the IPEEE results, it was necessary to review the changes to the site and surrounding area that were implemented after the completion of the IPEEE to determine if the changes could impact the conclusions of the external events analyses. The HCGS staff identified several major changes with the potential to impact the IPEEE results:

- Installation of security enhancements.
  - Installation of the vehicle barrier system
  - Elevation of the security guard bullet resistant enclosures
- Addition of the spent fuel storage facility
- Addition of a liquid oxygen storage tank off the corner of the Unit 2 Reactor Building

These changes are discussed in further detail below.

E.5.1.6.1.1 Security Changes

The security changes would not impact the fire, seismic, external flooding, transportation and fixed facility risk, or “other” external events. The only external event initiator relevant to HCGS that could potentially be impacted is the high winds risk. Given that raising the security guard bullet resistant enclosures did not introduce any new materials, no new wind generated missiles would be introduced to the site. Failure of the enclosure themselves does not impact plant risk.

The vehicle barriers are massive concrete blocks and based on engineering judgment, they do not present any wind based hazards that were not addressed in the IPEEE.

In conclusion, the addition of the security enhancements did not impact the results of the IPEEE and no SAMAs are required to address the security related changes.

E.5.1.6.1.2 Spent Fuel Storage Facility

The spent fuel storage facility is a large concrete pad that is separated from the site’s safety structures. The addition of the spent fuel storage facility would not impact the on-line plant risk for fire, seismic, external flooding, transportation and fixed facility risk, or “other” external events. It is possible an event could occur with one of these initiators that would result in a leaking storage cask, but NUREG 1864 (NRC 2007) estimates the probability of a latent cancer fatality from a fuel storage site to be 1.8E-12 during the first year of service, and 3.2E-14 per year during subsequent years of storage. The

NUREG 1864 analysis is not an HCGS specific study, but it is a good indicator that the risk associated with a leak of one of the casks is low compared with the on-line power generation risk. With respect to the potential for the cask to become a wind generated missile that could impact the plant, NUREG 1864 estimates that wins speeds of 400 mph would be required to slide the cask on the storage pad and over 600 mph to even tip the case over, which excludes this type of event from further consideration.

No SAMAs are suggested to address any risk associated with the spent fuel storage facility.

E.5.1.6.1.3 Liquid Oxygen Storage Tank

A liquid oxygen (LOX) storage tank has been placed just off the Northwest corner of Unit 2 Reactor Building. This tank is used for recombining H2 in the Radwaste facility. Plant personnel have indicated that the tank is secured to withstand high winds and that the risk associated with the tank in high wind scenarios is negligible. Although not seismically secure, the LOX tank is situated at a distance of approximately 300 ft from safety structures, eliminating it as an interaction hazard. While liquid O2 will support combustion in the presence of combustible materials under the right circumstances, it is not flammable and the consequences of a seismic event on this tank are determined to be negligible.

No SAMAs are suggested to address any risk associated with the liquid oxygen storage tank.

E.5.1.7 USE OF EXTERNAL EVENTS IN THE HCGS SAMA ANALYSIS

The IPEEE was used in the HCGS SAMA analysis primarily to identify the highest risk accident sequences and the potential means of reducing the risk posed by those sequences. The types of events considered in the HCGS external events analysis were identified by Supplement 4 of Generic Letter 88-20 (NRC 1991b) and included:

- Internal Fires
- Seismic Events
- High Wind Events

- External Flooding and Probable Maximum Precipitation
- Transportation and Nearby Facility Accidents

The generic letter also required that a review be performed to identify other types of potential hazards that could impact the plant to confirm that no plant specific issues were excluded by the IPEEE that could initiate severe accidents at HCGS. The HCGS IPEEE indicates that the guidance in NUREG-1407 and NUREG/CR-5042 was used to identify other potential initiating event (IE) types that could impact safe operation of the HCGS plant. These IEs were organized into the following categories for evaluation:

- Transportation and Nearby Facility Accidents
- External Floods (e.g., wind, precipitation, tide, and wave effects)
- Reduction of Secondary Heat Sink (e.g., low river level, ice blockage, detritus)
- High Winds and Tornadoes (e.g., wind and missile effects)
- Internal Fires
- Severe Weather Storms
- Severe Temperature Transients
- Internal Flooding
- Avalanche, Landslide, and Volcanoes
- Lightning
- External Fires
- Release of On-site Chemicals
- Seismic Events
- Soil Failure
- Turbine Missiles
- Extraterrestrial Activity

The HCGS IPEEE site evaluation concluded that the above list constituted a comprehensive list of credible, potential external event hazard initiators and no additional events were identified for evaluation. These potential contributors were evaluated using a progressive screening approach, per NUREG-1407, which resulted in the designation of seven initiators for more detailed analysis:

- Internal Fires (Section E.5.1.7.1)

- Seismic Events (Section E.5.1.7.2)
- High Wind Events (Section E.5.1.7.3)
- External Flooding and Probable Maximum Precipitation (Section E.5.1.7.4)
- Transportation and Nearby Facility Accidents (Section E.5.1.7.5)
- Release of On-site Chemicals (E.5.1.7.6)
- Detritus (E.5.1.7.7)

The type of information available for the initiators that were evaluated by HCGS varied due to the manner in which they were addressed in the IPEEE. For instance, PRAs were developed to evaluate the fire and seismic risk for HCGS while a progressive screening approach was employed to address the other external events contributors that were considered to be applicable to the site. While CDF results are available for the fire and seismic PRAs, the results of these analyses are not necessarily compatible with those of the internal events analysis. Specifically, the results are not linked to the current Level 2 and 3 PRA models and the consequences of the corresponding core damage scenarios are not available. In 2003, a partial update of the fire and seismic models was performed, but the changes were limited to the reassignment of some initiating event consequences (for fire events), initiating event frequency changes (fire and seismic), and fire severity factor updates. The integration of the fire and seismic models with the internal events PRA was not fully implemented and as a result, the underlying system and plant response models that these analyses rely upon have not been updated since the completion of the IPEEE in 1997.

Because of the differences in the methods used to evaluate the external events risks, each of the external event contributors must be considered in a manner suiting the type of analysis performed. A summary of the review process used to identify SAMAs is provided for each of the external event types listed above followed by a description of the method used to quantitatively incorporate external events contributions into the SAMA analysis.

E.5.1.7.1 Internal Fires

As discussed above, the techniques used to model external events vary according to the type of initiator being analyzed. The HCGS Fire Model shares many of the same characteristics as the internal events model and for HCGS, CDF results are available for the unscreened fire compartments. While this is true, limitations on the state of technology produce results that are potentially more conservative than the internal events model.

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

The HCGS modeling strategy makes use of PRA techniques, but neither the fire plant response model nor the fire modeling methodology is up to date. The methods are judged to result in overly conservative results. As a result, there are some factors that make it undesirable to use the CDF results directly with the internal events results. The following table summarizes these issues. In addition, the fire model is not integrated with the most recent Level 2 and 3 analyses that are available to support the SAMA analysis, which prevents the evaluation of accident consequences in a manner consistent with the process used for the internal events models.

PRA TOPIC	COMMENT
Initiating Events:	While the fire initiating event methodology is different than what is being used in current analyses, the 2003 HCGS External Events Update included changes to the initiating event frequencies based on the information provided in the 2002 NRC fire database (PSEG 2003).
System Response:	Several conservative assumptions are made with respect to the operation of plant systems due to lack of information and simplifying assumptions, which can increase the overall fire CDF. For example, Feedwater, Condensate, and CRD are assumed to be unavailable. Any fire, including an MCR fire, is assumed to result in a plant trip, even if it is not severe. Fire induced LOOP events are assumed to be unrecoverable as are loss of HVAC events for the class IE panel rooms. Fire suppression is credited, but modeling assumptions almost always result in the inability of the suppression system to extinguish fires before damage occurs to the ignition source.
Sequences:	Sequences in the HCGS fire model are defined in detail. The consequences of any sequence grouping is likely minor.

PRA TOPIC	COMMENT
Fire Modeling:	The 2003 HCGS External Events update (PSEG 2003) included the integration of the EPRI fire severity factors for control room fires, which is a change from the original IPEEE. Otherwise, the fire modeling from the IPEEE model has remained unchanged. In general, fire damage and fire spread are conservatively characterized. For example, Cable damage was calculated assuming all cables were unprotected, even if they were enclosed in cable trays or conduit. When determining damage to target cables from a specific source (in the absence of suppression), if any elevation of cable was calculated to be damaged, all of the cables were assumed to be damaged. When determining whether target cables were damaged from a specific source before extinguishment, if any elevation of cable was calculated to be damaged before extinguishment, all of the cables were assumed to be damaged. Any opening in a wall is assumed to allow fire damage to propagate via a hot gas layer as if the wall below the opening were not there. Exposure fires instantly attain their peak intensities and remain there for the duration of the fire. Targets respond with no delay to temperature changes in the surrounding environment. Heat loss by convection in ventilated room fires is neglected. Plume and hot gas layer temperature effects are superimposed to determine if targets have been damaged. Pump fires are modeled as liquid pool fires of quantity one or two gallons, whichever conservatively bounds the amount of lube oil in the pump.
HRA:	There is little industry experience with crew actions under conditions of the types of fires modeled in fire PRAs. This has generally led to conservative characterization of crew actions in fire PRAs. For HCGS, all recovery actions other than control of the plant from the remote shutdown panel and recovery of alternate 1E panel room HVAC were set to failure. However, the internal events HEPs for the other post-initiator HFEs and the pre-initiator HFEs were directly used in the fire model.
Level of Detail:	Many fire PRAs may have a reduced level of detail in the mitigation of the initiating events and consequential system damage; however, the HCGS model includes a detailed assessment of the impacts of the initiating events, consequential fire damage, and the subsequent response of the plant.
Quality of Model:	No peer review similar to what is performed for internal events models using the ASME Standard for PRA was performed on either the IPEEE fire model or the 2003 fire model.

While there are conservative factors included in the fire PRA, the fire PRA is still judged to include more conservative bias than an internal events model, the update of the fire initiating event frequencies and use of the HCGS 2003 External Events update for the CCDPs address a portion of the easily defined conservatisms (PSEG 2003). As a result, the SAMA analysis directly uses the updated fire CDF to develop the external events multiplier, as described in Section E.4.6.2.

The approach taken to identify potential fire-related SAMAs was to review the fire compartments with potential averted cost-risks (PACRs) greater than the minimum expected SAMA implementation cost of $100,000. The fire compartment PACRs were estimated by taking the external events PACR and distributing it among the fire scenarios based on the fire CDFs relative to the total site CDF. Review of additional fire scenarios is possible, but it is unlikely that any potentially cost beneficial SAMAs would be identified. Even if a cost beneficial SAMA were to be identified for scenarios with PACRs below $100,000, the averted cost-risk would be small (below $100,000) by definition and would not be a priority for implementation at the site. Consequently, the review effort for this analysis is limited to the fire scenarios with PACRs greater than $100,000.

The fire CDFs used to develop the fire scenario PACRs are based on the HCGS 2003 External Events update with the exception of the %IE-FIRE06 scenario. The CDF for this scenario has been reduced by a factor of 3 to reflect the availability of in-console halon suppression that can be initiated by the operators and/or the fire brigade. The factor of 3 reduction is based on the guidance in Appendix M of EPRI-105928 (EPRI 1995), which was used to develop the fire suppression frequency for HCGS in the 2003 External Events update. This results in the reduction of the %IEFIRE06 PACR from about $1,080,000 to $360,000; subsequent analysis demonstrates that this change does not impact the conclusions related to the SAMA identified to address this contributor.

The CDF results from that analysis are presented below for the top 10 contributors; of which only the top 8 have PACRs that are greater than $100,000.

BASIC EVENT ID	DESCRIPTION	FIRE IE FREQUENCY (/YR)	CCDP	FIRE CDF (/YR)	% OF FIRE CDF	COMPARTMENT FIRE MACR
%IE-FIRE03	Control Room Fire Scenario Small Cab_3 (Loss of Emer. Bat.)	2.94E-04	1.80E-02	5.29E-06	30.5%	$3,754,488
%IE-FIRE02	Control Room Fire Scenario Small Cab_2 (Loss of SSWS)	2.45E-04	1.80E-02	4.41E-06	25.4%	$3,128,740
%IE-FIRE01	Control Room Fire Scenario Small Cab_1 (Loss of SACS)	2.10E-04	1.80E-02	3.78E-06	21.8%	$2,681,777
%IE-FIRE28	Cmprtmnt 5339 Fire Scenario 5339_2	1.25E-05	6.00E-02	7.50E-07	4.3%	$532,099
%IE-FIRE37	DG Room (D) Fire Scenario 5304_2	1.00E-04	6.98E-03	6.98E-07	4.0%	$495,206
%IE-FIRE20	DG Room (C) Fire Scenario 5306_2	1.00E-04	6.67E-03	6.67E-07	3.8%	$473,213
%IE-FIRE38	Cmprtmnt 3425/5401 Fire Scenario 5401_1	3.40E-05	1.72E-02	5.85E-07	3.4%	$414,895
%IE-FIRE06	Control Room Fire Scenario Large Cab_1 (MSIV Closure)	2.55E-05	6.00E-02	5.10E-07	2.9%	$361,827
%IE-FIRE21	DG Room (B) Fire Scenario 5305_1	4.00E-03	2.09E-05	8.36E-08	0.5%	$59,311
%IE-FIRE24	Cmprtmnt 5501 Fire Scenario 5501_1	4.20E-04	1.90E-04	7.98E-08	0.5%	$56,615

For each fire compartment with a PACR greater than $100,000, the contributing risk factors were reviewed to determine what measures could be taken to mitigate the fire event and the corresponding core damage sequences. Further discussion is provided for each of these fire compartments below.

E.5.1.7.1.1 %IE-FIRE03: Control Room Fire Scenario Small Cab_3 (Loss of Emer. Bat.)

The definition of a "small" fire in the MCR is one that does not require abandonment to the remote shutdown panel (RSP) and that the damage caused by the fire is limited to the ignition component and the adjacent equipment. The fire addressed by this scenario is small, but a postulated hot short requires abandonment of the MCR and control of the plant at the RSP. In addition to the loss of the MCR, the fire fails the emergency batteries and inverters (related to control cable damage in the MCR). The fire scenario also accounts for the failure of the operator to shut the plant down from the RSP, which results in core damage.

A potential means of reducing the fire frequency is to install incipient fire detectors, which can identify hot points in the cables/circuit before fire ignition. However, credit for these types of systems has not been accepted within the industry and there is no quantitative basis for reducing the CDF based on the use of incipient fire detectors. As a result, installation of incipient fire detectors is not suggested as a SAMA.

The information provided for this fire scenario indicates that the required mitigation equipment is available and that it can be operated from the RSP; consequently, no additional hardware changes are required to improve defense-in-depth for the mitigating systems.

One of the factors driving the risk for this scenario is the limited credit that is taken for control of the plant at the RSP. This is due, at least in part, to the broad nature of the action. Current HRA methodologies do not effectively address an action as complex as shutting the reactor down from the RSP when taken as a single action. The failure probability does not provide insight into the factors that may be causing difficulty or even if there are any. While the particular difficulties associated with controlling the plant from the RSP are not well defined, it is clear that preventing MCR abandonment would preclude these challenges. By definition, this fire is small and does not require control room evacuation due to environmental issues; control from the RSP was assumed to be required because both divisions of the emergency batteries and inverters are damaged (even though the controls for the other systems remain available). A full MCR evacuation could be avoided if plant fire procedures were modified to allow the operators to transfer control of a single channel (“B” or “D”) of equipment to the RSP. The RSP could then be used to gain control of a single channel of critical equipment while the MCR is used to govern the other plant systems (SAMA 30). A different permutation of this SAMA would be to direct local control of the DC electrical system using the “A” or “C” trains to avoid use of the RSP altogether (guidance to use the “A” and “C” divisions currently exists as a backup to RSP control). While controlling a single system outside of the control room does present its own challenges, the scope of controlling a single system using an alternate set of controls is limited and could potentially improve the reliability of post fire plant control. It should be noted that the CDF for this scenario includes the assumption that the fire causes a single hot short (with a probability of 0.3) that disables the entire system. Division I and II equipment are generally separate and redundant such that a single hot short could not cause failure of both of the system’s divisions; however, this cannot be demonstrated without a circuit analysis, which is beyond the scope of the SAMA analysis. As a result, the assumption that a single hot short fails both divisions of the emergency batteries and inverters is retained for the SAMA analysis.

E.5.1.7.1.2 %IE-FIRE02: Control Room Fire Scenario Small Cab_2 (Loss of SSWS.)

This fire scenario is similar to %IE-FIRE03 in that a small MCR cabinet fire results in a hot short that forces abandonment to the RSP. In this case, the equipment damaged by the fire is the SSWS rather than the emergency batteries and inverters. The implication is that adequate systems are available to control the plant and that the RSP is operable, but the operators fail to control the plant from the RSP.

As for the %IE-FIRE03, the CDF calculation for this fire scenario also includes the assumption that a single hot short disables both divisions of a redundant plant system.

The same SAMA that is applicable to %IE-FIRE03 is also applicable to this scenario.

E.5.1.7.1.3 %IE-FIRE01: Control Room Fire Scenario Small Cab_1 (Loss of SACS)

This fire scenario is similar to %IE-FIRE03 in that a small MCR cabinet fire results in a hot short that forces abandonment to the RSP. In this case, the equipment damaged by the fire is the SACS rather than the emergency batteries and inverters. The implication is that adequate systems are available to control the plant and that the RSP is operable, but the operators fail to control the plant from the RSP.

As for the %IE-FIRE03, the CDF calculation for this fire scenario also includes the assumption that a single hot short disables both divisions of a redundant plant system.

The same SAMA that is applicable to %IE-FIRE03 is also applicable to this scenario.

E.5.1.7.1.4 %IE-FIRE06: Control Room Fire Scenario Large Cab_1 (MSIV Closure)

The impact of this fire scenario is similar to %IE-FIRE03 in that an MCR cabinet fire forces abandonment to the RSP, but in this case, both environmental factors and equipment damage issues contribute to the need to evacuate the MCR. Multiple systems are damaged by the fire, but the damage is limited to the MCR control consoles/cables and transfer to the RSP isolates the damaged circuits and adequate control is assumed to be available. Failure to control the plant using the RSP is a major contributor to the fire CDF.

Given that an in-console halon system exists in the HCGS MCR that can be quickly initiated by the operators and/or the plant’s fire brigade, credit for further manual or automatic fire suppression enhancements beyond what is described in Section E.5.1.7.1 is not considered to be available.

While further suppression improvements are not expected to have a significant impact on the fire CDF, improving the fire barriers in the control consoles containing the MSIV controls is a potential means of preventing fire propagation, which would greatly reduce the damage caused by the fire and prevent the need to evacuate the MCR due to poor environmental conditions (SAMA 31). Success of the fire barriers would effectively reduce the magnitude of the fire to a "small" fire and limit damage to a single console, which appears to only cause an MSIV closure event.

E.5.1.7.1.5 %IE-FIRE28: Cmprtmnt 5339 Fire Scenario 5339_2

The risk significant scenario of Room 5339 is one in which burning liquid fuel from a diesel-generator room fire leaks under the door separating the diesel-generator room from Room 5339. This area contains Division I cables, both sets of 1E 4kV bus bars, and the control power supply cables for diesel generators A and C. The dominant scenario is a large fire, from one of the four diesel-generator rooms, which spreads into this room causing loss of 4kV station power, loss of cables of Division I, and loss of the ability to start diesel-generators A and C. Calculation of the fire frequency for this scenario was taken to be 50% of the frequency of large fires calculated for all of the diesel generator rooms. That is, leakage under the door was assumed to occur for half of the scenarios in which a large pool might collect in any of the diesel generator rooms.

For this fire scenario, the 1E 4kV bus bars are damaged in the original EDG room fire, but it should be noted that these bus bars can be isolated from the division specific emergency 4kV buses that are supplied by the EDGs and feed the plant loads. If the fire does not reach Room 5339, the three remaining EDGs would be capable of starting and loading onto their division specific 4kV emergency buses. Once the fire reaches Room 5339, the A and C EDG control cables are damaged and Division I power is lost. SAMAs could be proposed to mitigate the effects of the fire that would primarily be composed of enhancements to provide alternate means of powering the important Division I equipment (potentially additional) cross-ties. However, a more cost effective means of mitigating this scenario would appear to be the installation of a curb or a diversion channel to ensure liquids from the DG rooms cannot communicate with Room 5339. (SAMA 32)

E.5.1.7.1.6 %IE-FIRE37: DG Room (D) Fire Scenario 5304_2

A large fire in this compartment will fail the D EDG and the 1E 4k emergency bus bars (fails offsite power to the emergency buses), but EDGs A, B, and C would be available to supply their loads, so the consequences of a fire that remains in this room alone are less severe than one that propagates into Room 5339 and fails the other channel of Division II power. Small fires do not damage the 1E 4kV emergency bus bars, but they do fail the EDG. The EDG rooms are equipped with total CO2 flooding systems, but they are not credited with preventing damage to either the EDGs or the bus bars.

The cause of the damage to the bus bars is the large fuel oil fire, which is assumed to be a result of either the plume or the ceiling jet from the fire. While installing an enhanced drain/sump type of a system could divert the majority of the fuel oil out from under the 4kV bus bars, the bars would still be in the ceiling jet and would still be failed by the fire. As a result, this type of a change, which is effective for preventing propagation of fuel oil to other rooms, is not considered to be effective in preventing damage to the 4kV bus bars.

A potential means of addressing the loss of the D EDG would be to install crossties between the Division II 480V AC buses (potentially 10B420 to 10B480 and 10B460 to 10B440). (SAMA 33)

E.5.1.7.1.7 %IE-FIRE20: DG Room (C) Fire Scenario 5306_2

This fire scenario is the same as the D EDG fire in Room 5304, but %IE-FIRE20 impacts the C EDG. Consequently, a similar SAMA is proposed for this scenario, but the crossties would be tailored to the Division I 480V AC bus design: 10B410 to 10B 430 and 10B450 to 10B470. (SAMA 34)

E.5.1.7.1.8 %IE-FIRE38: Cmprtmnt 3425/5401 Fire Scenario 5401_1

The information available in the IPEEE related to this fire is limited, but the fire event appears to be initiated by electrical heaters in the Electrical Access Area of the Auxiliary Building 124' level that are located within close proximity to some Division II cables. Automatic fire suppression systems are present, but they do not respond in time to prevent cable damage. The result of the fire is a plant trip with a loss of the B and D power divisions.

Inter-divisional cross-ties may be an effective means of mitigating these fires, but preventing the fire by moving or eliminating the electrical heaters is considered to be a more appropriate change. (SAMA 35)

E.5.1.7.1.9 Fire SAMA Identification Summary

Based on the review of the HCGS fire area results, six SAMAs have been identified as potentially cost beneficial methods of reducing fire risk:

- Modify fire procedures to allow partial transfer of controls to the RSP (SAMA 30)
- Install improved fire barriers in the MCR control cabinets containing the primary MSIV control circuits. (SAMA 31)
- Install a curb or a diversion channel to ensure liquids from the DG rooms cannot communicate with Room 5339. (SAMA 32)
- Install crossties between the Division II 480V AC buses (potentially 10B420 to 10B480 and 10B460 to 10B440). (SAMA 33)
- Install crossties between the Division I 480V AC buses (potentially 10B410 to 10B 430 and 10B450 to 10B470). (SAMA 34)
- Move or eliminate the electrical heaters in the electrical access room (Aux Building 124' level) to prevent damage to the Division II power cables. (SAMA 35)

E.5.1.7.2 Seismic Events

In response to Generic Letter 88-20, Supplement 4 (NRC 1991a), PSEG prepared a seismic PRA (SPRA) to asses seismic risk at the site. The SPRA considered site specific seismic event frequencies in conjunction with the plant specific response to quantify a CDF using the 1994 version of the HCGS internal events PRA model. The CDF for that internal event PRA model is 1.3E-5/yr, which is about a factor of 3.5 less than the HCGS IPE CDF of 4.58E-5/yr. The baseline case was originally developed using seismic hazard event frequencies developed by Lawrence Livermore National Labs (NRC 1994), but the EPRI seismic hazard curves (EPRI 1989) were also used in parallel as a sensitivity case.

Since completion of the IPEEE, the seismic results have been updated using the following information (PSEG 2003):

- The EPRI seismic hazard curves
- Revised treatment of HEPs under seismic conditions, to eliminate the non-conservative nature of the original seismic analysis
- The HCGS 2003A PRA model (calculates the CCDP)

The resulting CDF is 1.12E-06/yr. While the original intent of the HCGS 2003 External Events update was to facilitate the creation of an integrated PRA model, this change was not fully implemented and the External Events contributors are not maintained as a "living" analysis.

As with the fire analysis, the degree of refinement of the seismic model is not considered to be consistent with the internal events analysis. However, since the estimated CDF is low, effort will not be made in this analysis to detail these issues in order to justify a lower CDF for use in the External Events Multiplier (refer to Section E.4.6.3).

Table E.5.6.4 provides a summary of the changes made to the operator actions to support the 2003 HCGS seismic analysis (PSEG 2003):

The approach taken to identify potential seismic-related SAMAs was to review the seismic contributors with PACRs greater than the minimum expected SAMA implementation cost of $100,000. The seismic PACRs were estimated by taking the external events PACR and distributing it among the seismic damage states (SDSs) based on the seismic CDFs relative to the total site CDF. Review of additional seismic SDSs is possible, but it is unlikely that any potentially cost beneficial SAMAs would be identified. Even if a cost beneficial SAMA were to be identified for SDSs with PACRs below $100,000, the averted cost-risk would be small (below $100,000) by definition and would not be a priority for implementation at the site. Consequently, the review effort for this analysis is limited to the SDSs with PACRs greater than $100,000.

The CDFs used to develop the seismic PACRs are based on the HCGS 2003 External Events update (PSEG 2003). The CDF results from that analysis are presented below for the top 10 seismic contributors; only the top 2 scenarios have PACRs that are greater than $100,000.

BASIC EVENT ID	DESCRIPTION	SEISMIC HAZARD FREQUENCY (/YR)	CCDP	SEISMIC CDF (/YR)	% OF SEISMIC CDF	COMPARTMENT SEISMIC MACR
%IE-SET36	Seismic-Induced Equipment Damage State SET-36 (Impacts - 120V PNL481)	6.70E-07	1.00E+00	6.70E-07	5.98E-01	$475,341
%IE-SET18	Seismic-Induced Equipment Damage State SET-18 (Impacts - LOOP)	5.90E-05	5.20E-03	3.07E-07	2.74E-01	$217,806
%IE-SET37	Seismic-Induced Equipment Damage State SET-37 (Impacts - 125V)	5.50E-08	1.00E+00	5.50E-08	4.91E-02	$39,021
%IE-SET35	Seismic-Induced Equipment Damage State SET-35 (Impacts - 120V PNL482, RSP)	4.60E-08	1.00E+00	4.60E-08	4.11E-02	$32,635
%IE-SET38	Seismic-Induced Equipment Damage State SET-38 (Impacts - 1E Panel Room Ventil.)	2.10E-08	1.00E+00	2.10E-08	1.88E-02	$14,899
%IE-SET26	Seismic-Induced Equipment Damage State SET-26 (Impacts - LOOP, 250V)	1.10E-06	9.04E-03	9.94E-09	8.88E-03	$7,052
%IE-SET09	Seismic-Induced Equipment Damage State SET-09 (Impacts - 250V)	4.40E-07	1.04E-02	4.56E-09	4.07E-03	$3,235
%IE-SET34	Seismic-Induced Equipment Damage State SET-34 (Impacts - CR, RSP)	3.70E-09	1.00E+00	3.70E-09	3.30E-03	$2,625
%IE-SET28	Seismic-Induced Equipment Damage State SET-28 (Impacts - LOOP, 250V, CV)	1.00E-07	6.00E-03	6.00E-10	5.36E-04	$426

BASIC EVENT ID	DESCRIPTION	SEISMIC HAZARD FREQUENCY (/YR)	CCDP	SEISMIC CDF (/YR)	% OF SEISMIC CDF	COMPARTMENT SEISMIC MACR
%IE-SET30	Seismic-Induced Equipment Damage State SET-30 (Impacts - LOOP, 250V, CST)	1.00E-07	6.00E-03	6.00E-10	5.36E-04	$426

For each seismic scenario with a PACR greater than $100,000, the contributing risk factors were reviewed determine what measures could be taken to mitigate the seismic event and the corresponding core damage sequences. Further discussion is provided for each of these scenarios below.

E.5.1.7.2.1 %IE-SET36: Seismic-Induced Equipment Damage State SET-36 (Impacts - 120V PNL481)

This seismic damage state represents a seismic-induced failure of all four divisions of 1E 120Vac instrumentation distribution panels 1A/B/C/DJ481. Core damage is assumed to occur given these failures. It is possible to control the plant without class 1E instrumentation power, but it is not proceduralized.

Providing adequate procedural guidance in the MCR to operate the plant after a total loss of class 1E 120V AC power would provide some benefit for these scenarios. (SAMA 36) Guidance is available at the RSP to perform the tasks that would be required without 120V AC power (mainly manually operating equipment that is typically automatically operated), but these functions can be performed directly from the MCR.

An alternate option is to reinforce the 120V AC distribution panels so that they could survive more severe seismic activity. (SAMA 37)

E.5.1.7.2.2 %IE-SET18: Seismic-Induced Equipment Damage State SET-18 (Impacts - LOOP)

This scenario represents a seismic-induced loss of offsite power, with subsequent random failures which result in core damage. No other seismically induced failures are identified for the scenario. The random failures are dominated by Emergency Diesel Generator failures, resulting in a Station Blackout.

A potential means of addressing these contributors would be to provide a 24 hour fuel oil source for the engine driven fire water pump and use the existing portable 480V AC generator to power bus 10B421 to support SRV operation. Use of the portable battery charger provides RPV depressurization capability to allow low pressure injection with fire water (fire water can be aligned manually). In addition, the fire water tanks have HCLPF values of 0.26g and may need to be strengthened to match the engine driven fire pump's HCLPF in order to improve the likelihood that fire water injection will be available in a seismic event. (SAMA 38)

The SDS description does not indicate that the fire water system has failed, but the fire water system is currently not credited in the seismic analysis for RPV injection and information about fire water availability would not be tracked or presented for this SDS.

E.5.1.7.2.3 Seismic SAMA Identification Summary

Based on the review of the HCGS SDS results, three SAMAs have been identified as potentially cost beneficial methods of reducing seismic risk:

- Develop MCR procedures to operate the plant after a loss of all class 1E 120V AC power. (SAMA 36)
- Reinforce the class 1E 120V AC distribution panels. (SAMA 37)
- Enhance the Fire Water system and use the existing portable generator to support SRV operation for long term injection in seismic events. (SAMA 38)

E.5.1.7.3 High Wind Events

The approach taken to analyze the high wind, flood, and "other" external event risk in the HCGS IPEEE was to implement a progressive screening approach. The first three steps included 1) a review of HCGS specific hazard data and licensing basis, 2) identification of significant changes since Operating License issuance, and 3) verification that the HCGS design met the 1975 SRP criteria. An affirmative determination that the 1975 SRP screening criteria were met resulted in the screening of the hazard on the basis that conformance to the SRP met the IPEEE screening criterion.

For the SAMA analysis, this process is considered adequate for screening events that do not pose a credible threat to plant operations. However, any issues that could impact plant safety are reconsidered to determine if the development of a SAMA is appropriate to address the risk.

Based on the review performed at the site, it was determined that the plant safety equipment was not vulnerable to the effects of high winds with the exception of the rain hoods on the EDG exhaust pipes and the rain hoods on the EDG fuel oil tank vents. The EDG fuel oil tanks have alternate vent lines that could be used in the event that the primary vents are damaged, which is considered to be adequate redundancy. The EDG exhaust pipes, which could potentially be damaged by a wind generated missile, would have to be first be impacted by a missile and then damaged to the point where they could not function. The IPEEE indicated that the UFSAR evaluated such a strike and concluded that it was very unlikely a wind generated missile strike would adversely impact the function of the exhaust pipes.

Even if the high wind core damage frequency is assumed to be as high as the IPEEE’s screening threshold of 1E-06/yr, some high level assumptions can be used to generated a PACR for the EDG exhaust pipes to show that further investigation of this topic is not required. If the same process used in Section E.5.1.8.1 to estimate the fire area PACRs is used for the high wind risk, a high wind CDF of 1E-06/yr can be correlated to a cost-risk of about $590,000. If a missile strike on the EDG exhaust pipes that completely disables one or more EDGs is assumed to account for as much as 10 percent of this risk, the corresponding PACR is only $59,000, which is significantly less than the lower bound cost of a procedure change. No SAMAs are suggested to address this issue.

The only other high wind issue identified in the IPEEE was related to inadequate doors on the TSC, which was addressed through the installation of missile barriers.

In conclusion, no high wind related SAMAs are required for HCGS.

E.5.1.7.4 External Flooding and Probable Maximum Precipitation

Site flooding at HCGS is addressed by the probable maximum hurricane surge with wave run-up coincident with the ten percent exceedance high tide. Safety related systems and components are not affected by a flood when they are located above the postulated maximum flood level. When located below flood level, the HCGS structures were found to be protected against water ingress and no vulnerabilities were identified.

In addition, probable maximum precipitation events were examined for the site and the safety structures were determined not to be vulnerable to stresses related to "ponding" or snow accumulation.

Given the low potential for identifying cost beneficial SAMAs to mitigate risk posed by external flooding, no further efforts were made in the SAMA analysis to develop SAMAs related to external flooding events.

E.5.1.7.5 Transportation and Nearby Facility Accidents

Transportation and nearby facility accidents were included in the HCGS IPEEE to account for human errors or equipment failures that may occur in events not directly related to the power generation process at the plant. The types of hazards considered for analysis included:

- Transportation Accidents
  - Accidental Aircraft Strike
  - Road and Rail
  - River shipping
- Fixed Facility Accidents
  - Industrial Facilities
  - Military Facilities
  - Pipeline Accidents

It is recognized that the types of credible threats to nuclear facilities by aircraft have changed since the time the IPEEE was published. While this is true, efforts are underway within the industry to address this issue in conjunction with other forms of sabotage. Based on the fact that this topic is currently being analyzed in another forum and due to the complexity of the issue, intentional aircraft impact events are considered to be out of the scope of the SAMA analysis. Accidental aircraft impact was reviewed in the IPEEE and a previous analysis was cited that estimated the frequency of a strike with a potential for causing radiological consequences in excess of the exposure guidelines of 10CFR100 was 6.7E-08 per year. Even if the conditional CDF is assumed to be 1.0 after an aircraft impact, the CDF is 275 times less than the IPEEE internal fire CDF of 1.84E-05 per yr and over 115 times less than the current internal events CDF. If the same process used in Section E.5.1.8.1 to estimate the fire area PACRs is used for the accidental aircraft impact PACR, an aircraft strike CDF of 6.7E-08/yr can be correlated to a cost-risk of about $48,000 (assuming a 1.0 conditional core damage probability). Given the relatively low risk of aircraft impact compared with fire risk, no further efforts were made in the SAMA analysis to develop plant enhancements related to accidental aircraft protection.

The road and railway loading around HCGS was analyzed for the IPEEE and it was determined that because no major highway or rail line was located within a 5 mile radius of the plant, the impact of any transportation accidents on those types of routes was negligible. No SAMAs are required to address these types of events.

The fixed facility accidents, including pipeline breaks, industrial accidents, and accidents from nearby military bases, were reviewed in the IPEEE and it was determined that none of these elements posed credible threats to safe plant operation. There were no such facilities located within a 5-mile-radius of the site and the threats from these types of accidents were considered to be negligible. Given the low potential for identifying cost beneficial SAMAs to mitigate risk posed by the fixed facility accidents, no further efforts were made in the SAMA analysis to develop SAMAs related to these hazards.

E.5.1.7.6 "Other" Events

Because some hazardous chemicals are stored at, delivered to, and used at the HCGS site, it was necessary to examine the impact of chemical releases on plant operations. The IPEEE indicates that HCGS conforms to Regulatory Guide 1.78 and that control room habitability would not be impacted by any postulated accidents. No SAMAs are suggested.

E.5.1.7.7 Detritus

Detritus was also examined for HCGS in the IPEEE given that the site had experienced problems due to mud and grass buildup on the Service Water system traveling screens. While traveling screen clogging was an issue, the IPEEE indicates that a large scale river bottom perturbation would be required to dislodge sufficient detritus to impact all Service Water intakes. A seismically induced detritus event was evaluated for HCGS, but it was screened from the IPEEE based on a 1995 PSEG analysis that estimated the CDF for such an event to range from about 5E-07/yr to about 9E-07/yr. The risk from this type of event was considered to be low and it did not account for all of the changes that had been made to the Service Water system. As a result, no additional changes were considered to be required to reduce the risk of detritus events in the IPEEE. If the same process used in Section E.5.1.7.1 to estimate the fire area PACRs is used for the seismically induced detritus risk, a CDF of 5.2E-07/yr can be correlated to a cost-risk of about $370,000. Based on the information available in the IPEEE related to detritus events, no additional procedure enhancements that would significantly reduce risk have been identified beyond those enhancements that have already been made, which would imply only hardware changes would be available to further reduce detritus risk. However, no credible, potentially cost beneficial SAMAs have been identified that would significantly reduce the risk of seismically induced detritus events.

It is noted that events involving SW intake at the site have primarily affected the Salem unit because of the location of the Salem intake and the large intake flow rate required for Salem (no cooling tower). For Hope Creek, the intake is located in a more benign location and the intake flow rate is significantly lower than for Salem because the CW is taken from the cooling tower basin not the river. The river intake is for SW only and is relatively low compared with Salem intake throughput.

E.5.2 PHASE 1 SCREENING PROCESS

The initial list of SAMA candidates is presented in Table E.5-3. The process used to develop the initial list is described in Section E.5.1.

The purpose of the Phase 1 analysis is to use high-level knowledge of the plant and SAMAs to preclude the need to perform detailed cost-benefit analyses on them. The following screening criteria were used:

- Applicability to the Plant: If a proposed SAMA does not apply to the HCGS design, it is not retained. Similarly, any SAMAs that have already been implemented by PSEG or achieve results that PSEG has achieved by other means can be screened as they are not applicable to the current plant design. The use of these criteria is not often explicitly used in the Phase I analysis because the SAMA methodology generally precludes inclusion of such SAMAs; however, they are listed as a possible screening methods given that there may be circumstances in which a SAMA would be included in the list even if it is not relevant to the site. An example may be the inclusion of a high profile SAMA that is well known in the industry, but not applicable to the specific site design. Such a SAMA may be included for documentation purposes. Another example may be an unimplemented SAMA from the IPE that has been superseded by another plant enhancement.
- Implementation Cost Greater than Screening Cost: If the estimated cost of implementation is greater than the modified MACR (refer to Section E.4.6), the SAMA cannot be cost beneficial and is screened from further analysis.

Table E.5-3 provides a description of how each SAMA was dispositioned in Phase 1. Those SAMAs that required a more detailed cost-benefit analysis are passed to the Phase 2 analysis and evaluated in Section E.6. Table E.6-1 contains the Phase 2 SAMAs.

E.6 PHASE 2 SAMA ANALYSIS

The SAMA candidates identified as part of the Phase 2 analysis are listed in Table E.6-1. The base PRA model was manipulated to simulate implementation of each of the proposed SAMAs and then quantified to determine the risk benefit. In general, in order to maximize the potential risk benefit due to implementation of each of the SAMAs, the failure probabilities assigned to new basic events, such as HEPs, were optimistically chosen so as not to inadvertently screen out any potential cost-beneficial SAMAs. Also, any new model logic that was added to the PRA model in order to simulate SAMA implementation was also simplified and optimistically configured to achieve the same effect.

Determination of the cost-risk benefit for each of the Phase 2 SAMAs involved calculating what was known as the averted cost-risk, which was obtained by comparing the SAMA results with the base case MMACR value. This value is then compared with the cost of implementation to determine the overall net benefit. That is, the net value is determined by the following equation:

Net Value = (baseline cost-risk of plant operation (MMACR) – cost-risk of plant operation with SAMA implemented) – cost of implementation

If the net value of the SAMA is negative, the cost of implementation is larger than the benefit associated with the SAMA and the SAMA is not considered cost beneficial. The baseline cost-risk of plant operation was derived using the methodology presented in Section E.4. The cost-risk of plant operation with the SAMA implemented is determined in the same manner with the exception that the revised PRA results reflect implementation of the SAMA.

The implementation costs used in the Phase 1 and 2 analyses consist of HCGS specific estimates developed by plant personnel. Table E.5-3 provides implementation costs for each Phase 1 and Phase 2 SAMA.

Sections E.6.1 – E.6.21 describe the simplified cost-benefit analysis that was used for each of the Phase 2 SAMA candidates. It should be noted that the release category results provided for each SAMA do not include contributions from the negligible release category.

E.6.1 SAMA 1: REMOVE ADS INHIBIT FROM NON-ATWS EMERGENCY OPERATING PROCEDURES

In most initiating events the operators are directed to inhibit ADS. This requires them to later manually depressurize to allow low pressure injection from low pressure systems. The ADS feature is inhibited so as to prevent premature depressurization and allow the operator to control the time when depressurization occurs. This SAMA investigates the basis for inhibiting ADS and provides alternatives (e.g., removing the ADS inhibit from the EOP for non-ATWS scenarios). Although this is contrary to the recommendations from the BWROG EOP guidelines, it may have a large impact on the risk reduction. The other alternative would be to install a separate and totally independent high pressure injection system to mitigate those sequences where the normal high pressure injection systems are unavailable. However, due to the large perceived cost with this type of permanent modification, it was decided to analyze the aforementioned lower cost option that involves changing the procedure that directs the operator to inhibit the ADS.

Assumptions:

1. For the purposes of this SAMA, it was assumed that the operator would not inhibit ADS.
2. The ADS inhibit function would still be required for ATWS sequences.

PRA Model Changes to Model SAMA:

The operator action to inhibit ADS (ADS-XHE-OK-INHIB) probability was changed from 1.0 to 1E-1. The 1E-1 represents the HEP for the operator inappropriately inhibiting ADS for non-ATWS scenarios. This high failure rate can later be reduced after training and sufficient experience with this change in place. No other basic events or fault tree structures were affected.

Results of SAMA Quantification:

Implementation of this SAMA yields a large reduction in the CDF, Dose-Risk and Offsite Economic Cost-Risk. The results are summarized in the following table for HCGS:

	CDF	Dose-Risk	OECR
Base Value	4.44E-06	22.86	$155,055
SAMA Value	3.28E-06	16.30	$114,734
Percent Change	26.2%	28.7%	26.0%

A further breakdown of the Dose-Risk and OECR information is provided in the below table according to release category:

RELEASE CATEGORY	ST1	ST2	ST3	ST4	ST5	ST6	ST7	ST8	ST9	ST10	ST11	TOTAL
$Frequency_{BASE}$	1.83E-07	7.15E-08	1.30E-07	9.70E-07	8.34E-08	3.48E-07	2.16E-07	0.00E+00	2.68E-07	2.39E-07	1.93E-06	**4.44E-06**
$Frequency_{SAMA}$	1.26E-07	7.15E-08	3.04E-08	9.67E-07	8.28E-08	1.08E-07	2.15E-07	0.00E+00	2.57E-07	2.36E-07	1.18E-06	**3.28E-06**
$Dose\text{-}Risk_{BASE}$	3.33	0.99	3.05	8.49	0.92	4.55	1.37	0.00	0.00	0.16	0.00	**22.86**
$Dose\text{-}Risk_{SAMA}$	2.29	0.99	0.71	8.46	0.91	1.42	1.36	0.00	0.00	0.16	0.00	**16.30**
$OECR_{BASE}$	$21,045	$6,888	$14,975	$62,159	$7,694	$31,881	$10,235	$0	$0	$177	$0	**$155,055**
$OECR_{SAMA}$	$14,454	$6,888	$3,497	$61,971	$7,643	$9,927	$10,178	$0	$0	$175	$0	**$114,734**

This information was used as input to the cost-benefit calculation. The results of this calculation are provided in the following table:

SAMA 1 NET VALUE

UNIT	BASE CASE COST-RISK	REVISED COST-RISK	AVERTED COST-RISK
Hope Creek	$19,807,200	$14,539,581	$5,267,619

Based on a $200,000 cost of implementation for HCGS, the net value for this SAMA is $5,067,619 ($5,267,619 - $200,000), which results in this SAMA being cost beneficial.

It should be noted that implementation of this SAMA would have a limited impact on external events initiators and that the use of the external events multiplier for the averted cost-risk calculation results in an unrealistically high estimate of the cost benefit. For example, for the three dominant fire scenarios, which account for about 60 percent of the external events risk, the ADS function is irrelevant to the core damage frequency.

The scenarios are dominated by failure to control the plant from the RSP; even if ADS functions, core damage would still occur for those scenarios. In order to assess the importance of the external events contributions on this SAMA's evaluation, the averted cost-risk has been estimated without the use of the external events multiplier. In this case, the internal events based averted cost-risk for SAMA 1 is $836,130, which is greater than the $200,000 cost of implementation.

An additional factor to consider is that implementation of this SAMA would increase the complexity of the EOPs by creating a situation where the use of ADS inhibit is not consistent for all accident scenarios. A potential undesired consequence of such a change would be an increased likelihood that ADS would not be inhibited in ATWS events (or inhibited in non-ATWS events). The quantification performed for this SAMA does not include any detrimental impacts related to implementation; however, any related CDF increases are expected to be small and the SAMA would remain cost beneficial. Even if the negative impacts of implementation were assumed to reduce the benefit of the SAMA by as much as 50 percent, the internal events averted cost-risk would be more than double the cost of implementation at $418,065.

Given that the implementation cost was estimated to be $200,000, this SAMA would be cost beneficial even if any potential negative impacts associated with implementation are accounted for and the averted cost-risk were only based on internal events contributors

E.6.2 SAMA 3: INSTALL BACK-UP AIR COMPRESSOR TO SUPPLY AOVs

Following the loss of the service water system, the PRA includes a recovery action to restore failed equipment, specifically, to restore Service Water and reestablish SACS given a loss of Service Water. Currently, there is no specific procedural direction for this action. This action involves damage repair and recovery as part of Emergency Response Organization (ERO) activities.

This SAMA involves replacing the operator action to repair or restore (NR-IE-SWS) with a backup air compressor. The air compressor would be utilized to allow use of AOVs which would allow operators to mitigate the loss of service water.

Assumptions:

1. For the purposes of this SAMA, it was assumed that this system would require manual initiation.
2. This backup air compressor system would rely upon current AC power sources.
3. A combined HRA and hardware failure probability of 0.5 was selected as a screening

PRA Model Changes to Model SAMA:

It should be noted that the degree of recovery attached to failures of AOV valves is judged to be only a small fraction of the probability for loss of SW. The operator action to recover service water (NR-IE-SWS) probability was changed from 1.0 to 0.5. This event represents a legacy event from previous models, but is no longer credited for recovery of service water in the HC108B model. This change would simulate the addition of an OR gate which would contain the backup air compressor. No other basic events or fault tree structures were affected.

Results of SAMA Quantification:

Implementation of this SAMA yielded an appreciable reduction in CDF and similar changes in Dose-Risk and Offsite Economic Cost-Risk. The results are summarized in the following table for HCGS:

	CDF	**DOSE-RISK**	**OECR**
Base Value	4.44E-06	22.86	$155,055
SAMA Value	3.72E-06	19.26	$128,757
Percent Change	16.3%	15.8%	17.0%

A further breakdown of the Dose-Risk and OECR information is provided in the below table according to release category:

RELEASE CATEGORY	ST1	ST2	ST3	ST4	ST5	ST6	ST7	ST8	ST9	ST10	ST11	TOTAL
$Frequency_{BASE}$	1.83E-07	7.15E-08	1.30E-07	9.70E-07	8.34E-08	3.48E-07	2.16E-07	0.00E+00	2.68E-07	2.39E-07	1.93E-06	**4.44E-06**
$Frequency_{SAMA}$	1.82E-07	5.15E-08	1.30E-07	6.29E-07	5.75E-08	3.48E-07	2.16E-07	0.00E+00	1.97E-07	1.73E-07	1.73E-06	**3.72E-06**
$Dose\text{-}Risk_{BASE}$	3.33	0.99	3.05	8.49	0.92	4.55	1.37	0.00	0.00	0.16	0.00	**22.86**
$Dose\text{-}Risk_{SAMA}$	3.32	0.71	3.05	5.51	0.63	4.55	1.37	0.00	0.00	0.12	0.00	**19.26**
$OECR_{BASE}$	$21,045	$6,888	$14,975	$62,159	$7,694	$31,881	$10,235	$0	$0	$177	$0	**$155,055**
$OECR_{SAMA}$	$20,973	$4,959	$14,975	$40,334	$5,307	$31,881	$10,200	$0	$0	$128	$0	**$128,757**

This information was used as input to the cost-benefit calculation. The results of this calculation are provided in the following table:

SAMA 3 NET VALUE			
UNIT	**BASE CASE COST-RISK**	**REVISED COST-RISK**	**AVERTED COST-RISK**
Hope Creek	$19,807,200	$16,505,055	$3,302,145

Based on a $700,000 cost of implementation for HCGS, the net value for this SAMA is $2,602,145 ($3,302,145 - $700,000), which results in this SAMA being cost beneficial.

E.6.3 SAMA 4: PROVIDE PROCEDURAL GUIDANCE TO CROSS-TIE RHR TRAINS

The ability to repair or recover RHR equipment that is failed or out of service can have a dramatic impact on the course of postulated accident sequences. For example, the loss of containment heat removal sequences may evolve over extended times of 15 - 50 hours. During this time frame, there can be extensive repair activities accomplished to restore equipment to service. The PRA includes these repair activities (RHS-REPAIR-TR). Currently only one pump within the loop is capable of being aligned to perform the torus cooling function.

This SAMA involves replacing recovery activity to repair or restore RHR (NR-IE-SWS) with an operator action to cross tie the existing RHR pumps to allow either to perform the heat removal functions. This change requires procedure and operator training to realize the benefit of this SAMA.

Assumptions:

1. For the purposes of this SAMA, it was assumed that this system would require manual operation.
2. This motor operator valve manipulation would rely upon current AC power sources.
3. A combined HRA and hardware failure probability of 1E-1 was selected as a screening

PRA Model Changes to Model SAMA:

The operator action to recover RHR (RHS-REPAIR-TR) probability was changed from 3.5E-1 to 1E-1.This change would simulate the conditional probability that RHR could be recovered by crosstying pumps within the loop. No other basic events or fault tree structures were affected.

Results of SAMA Quantification:

Implementation of this SAMA yielded a slight reduction in the CDF with larger reductions in Dose-Risk and Offsite Economic Cost-Risk. The results are summarized in the following table for HCGS:

	CDF	DOSE-RISK	OECR
Base Value	4.44E-06	22.86	$155,055
SAMA Value	3.89E-06	18.04	$119,730
Percent Change	12.4%	21.1%	22.8%

A further breakdown of the Dose-Risk and OECR information is provided in the below table according to release category:

RELEASE CATEGORY	ST1	ST2	ST3	ST4	ST5	ST6	ST7	ST8	ST9	ST10	ST11	TOTAL
$Frequency_{BASE}$	1.83E-07	7.15E-08	1.30E-07	9.70E-07	8.34E-08	3.48E-07	2.16E-07	0.00E+00	2.68E-07	2.39E-07	1.93E-06	**4.44E-06**
$Frequency_{SAMA}$	1.83E-07	7.15E-08	1.30E-07	4.19E-07	8.34E-08	3.48E-07	2.16E-07	0.00E+00	2.68E-07	2.39E-07	1.93E-06	**3.89E-06**
$Dose\text{-}Risk_{BASE}$	3.33	0.99	3.05	8.49	0.92	4.55	1.37	0.00	0.00	0.16	0.00	**22.86**
$Dose\text{-}Risk_{SAMA}$	3.33	0.99	3.05	3.66	0.92	4.55	1.37	0.00	0.00	0.16	0.00	**18.04**
$OECR_{BASE}$	$21,045	$6,888	$14,975	$62,159	$7,694	$31,881	$10,235	$0	$0	$177	$0	**$155,055**
$OECR_{SAMA}$	$21,045	$6,888	$14,975	$26,834	$7,694	$31,881	$10,235	$0	$0	$177	$0	**$119,730**

This information was used as input to the cost-benefit calculation. The results of this calculation are provided in the following table:

SAMA 4 NET VALUE

UNIT	BASE CASE COST-RISK	REVISED COST-RISK	AVERTED COST-RISK
Hope Creek	$19,807,200	$15,449,074	$4,358,126

Based on a $100,000 cost of implementation for HCGS, the net value for this SAMA is $4,258,126 ($4,358,126 - $100,000), which results in this SAMA being cost beneficial.

E.6.4 SAMA 5: RESTORE AC POWER WITH ONSITE GAS TURBINE GENERATOR

After a loss of offsite power with a failure of all EDGs or failure of some EDGs combined with failure of EDG supported equipment (i.e., ECCS trains) operators may wish to cross-tie certain equipment. This action can link electrical supply with otherwise operational equipment. Currently there is no operational capability or procedural guidance to cross-tie 4.160 kv loads between Hope Creek electrical divisions. Repair of damaged equipment is considered separately from procedurally guided operator action. As such, these actions involve damage repair and recovery as part of Emergency Response Organization (ERO) activities. During operator interviews the operators confirmed that they would not cross the EDGs from one division to another. Based on this input this recovery action (NR-XTIE-EDG) is set to 1.0.

A 40 MWe gas turbine generator is located adjacent to the Hope Creek plant, inside the Salem Generating Station's protected area. This equipment is capable of supplying power to the Hope Creek 13.8kv system via the local Salem 500kv system. The gas turbine is operated by Salem personnel. Hope Creek operators must coordinate its use with Salem Plant Staff. This task involves requesting alignment of the gas turbine and coordinating electrical system manipulations with Salem staff as well as regional power control staff.

This SAMA involves replacing the EDG cross tie activity (NR-XTIE-EDG) with an operator action to take more advantage of the existing Salem Gas Generator. This change requires procedure and operator training to realize the benefit of this SAMA.

<u>Assumptions:</u>

1. For the purposes of this SAMA, it was assumed that this system would require manual operation.
2. The additional breaker manipulation would rely upon current AC power equipment.
3. A combined HRA and hardware failure probability of 1E-1 was selected as a screening

<u>PRA Model Changes to Model SAMA:</u>

The operator action cross tie emergency diesels (NR-XTIE-EDG) probability was changed from 9.9E-1 to 1E-1.This change would simulate improvement of increasing the use of the Salem Gas Generator. No other basic events or fault tree structures were affected.

<u>Results of SAMA Quantification:</u>

Implementation of this SAMA yielded a significant reduction in the CDF, Dose-Risk and Offsite Economic Cost-Risk. The results are summarized in the following table for HCGS:

	CDF	DOSE-RISK	OECR
Base Value	4.44E-06	22.86	$155,055
SAMA Value	4.10E-06	22.08	$149,815
Percent Change	7.7%	3.4%	3.4%

A further breakdown of the Dose-Risk and OECR information is provided in the below table according to release category:

RELEASE CATEGORY	ST1	ST2	ST3	ST4	ST5	ST6	ST7	ST8	ST9	ST10	ST11	TOTAL
$Frequency_{BASE}$	1.83E-07	7.15E-08	1.30E-07	9.70E-07	8.34E-08	3.48E-07	2.16E-07	0.00E+00	2.68E-07	2.39E-07	1.93E-06	**4.44E-06**
$Frequency_{SAMA}$	1.57E-07	7.15E-08	1.30E-07	9.45E-07	8.34E-08	3.47E-07	2.04E-07	0.00E+00	2.56E-07	2.39E-07	1.67E-06	**4.10E-06**
$Dose\text{-}Risk_{BASE}$	3.33	0.99	3.05	8.49	0.92	4.55	1.37	0.00	0.00	0.16	0.00	**22.86**
$Dose\text{-}Risk_{SAMA}$	2.86	0.99	3.05	8.27	0.92	4.54	1.30	0.00	0.00	0.16	0.00	**22.08**
$OECR_{BASE}$	$21,045	$6,888	$14,975	$62,159	$7,694	$31,881	$10,235	$0	$0	$177	$0	**$155,055**
$OECR_{SAMA}$	$18,045	$6,888	$14,975	$60,590	$7,694	$31,782	$9,664	$0	$0	$177	$0	**$149,815**

This information was used as input to the cost-benefit calculation. The results of this calculation are provided in the following table:

SAMA 5 NET VALUE

UNIT	BASE CASE COST-RISK	REVISED COST-RISK	AVERTED COST-RISK
Hope Creek	$19,807,200	$19,102,652	$704,548

Based on a $2,050,000 cost of implementation for HCGS, the net value for this SAMA is -$1,345,452 ($704,548 - $2,050,000), which results in this SAMA not being cost beneficial.

E.6.5 SAMA 7: INSTALL BETTER FLOOD DETECTION INSTRUMENTATION FOR RACS COMPARTMENT

The Service Water system has two trains (A and B). The A and B trains are normally isolated from each other and supply loads that are dedicated to their train. As such, a rupture of one train will in general be isolable to terminate the discharge of flow to the Reactor Building. There is an exception for short runs of unisolable SW discharge pipe located in the Reactor Building. For certain postulated unisolated breaks in the SW discharge inside the RACS room, SW will continue to discharge to the RACS room because of either (1) continued operation of the opposite SW train which results in continued back flow through the break from the discharge; or, (2) reverse flow from the Cooling Tower Basin.

The SW discharge to the Cooling Tower Basin traverses the HCGS yard. There are valves located in 4 ft. deep pits in the HCGS yard (within the Protected Area). The internal flood walkdown identified that these valves are located in a “confined space” underground in the HCGS yard within the Protected Area. These isolation valves are located below grade and are accessed via man-ways in the yard between the plant buildings and the cooling tower. These are large valves and are difficult to manipulate. Operations staff interviewed indicated that closing the valves would require at least 1-2 hours if remote operation of the valves was unavailable. Further, during a plant walkdown in March 2008, the man-ways were observed to be flooded with ground water making accessibility especially difficult if not unachievable within a reasonable amount of time. These valves are the only way to isolate a small portion of the SW pipe within the Reactor Building (RACS compartment) if they rupture. Flooding from the Cooling Tower basin to the RACS room can occur due to reverse flow. It is determined that these valves do not represent viable methods of isolating the relatively large leaks that are postulated as part of the internal flood analysis. This is principally due to the following:

- Located in the yard
- Located in a confined space (requires special consideration)
- Under water
- Difficult to turn (under these time limited conditions)

Remote operation is not guaranteed

Assumptions:

1. For the purposes of this SAMA, it was assumed that this system would require manual operation from the control room.
2. Failure of the new MOV to close on demand is negligible.
3. A HRA failure probability of 1E-1 was selected as a screening value

PRA Model Changes to Model SAMA:

The operator action "FAILURE TO ISOLATE LOCALLY A SW RUPTURE IN RACS COMPARTMENT" (SWS-XHE-RACS-UNI) probability was changed from 1 to 1.0E-1. This change would simulate a motor operated valve failure combined with the failure of the operator to isolate the break. No other basic events or fault tree structures were affected.

Results of SAMA Quantification:

Implementation of this SAMA yielded a slight reduction in the CDF, Dose-Risk and Offsite Economic Cost-Risk. The results are summarized in the following table for HCGS:

	CDF	DOSE-RISK	OECR
Base Value	4.44E-06	22.86	$155,055
SAMA Value	4.27E-06	22.52	$152,597
Percent Change	3.8%	1.5%	1.6%

A further breakdown of the Dose-Risk and OECR information is provided in the below table according to release category:

RELEASE CATEGORY	ST1	ST2	ST3	ST4	ST5	ST6	ST7	ST8	ST9	ST10	ST11	TOTAL
$Frequency_{BASE}$	1.83E-07	7.15E-08	1.30E-07	9.70E-07	8.34E-08	3.48E-07	2.16E-07	0.00E+00	2.68E-07	2.39E-07	1.93E-06	**4.44E-06**
$Frequency_{SAMA}$	1.83E-07	6.36E-08	1.30E-07	9.70E-07	6.54E-08	3.48E-07	2.16E-07	0.00E+00	2.27E-07	1.96E-07	1.87E-06	**4.27E-06**
$Dose\text{-}Risk_{BASE}$	3.33	0.99	3.05	8.49	0.92	4.55	1.37	0.00	0.00	0.16	0.00	**22.86**
$Dose\text{-}Risk_{SAMA}$	3.33	0.88	3.05	8.49	0.72	4.55	1.37	0.00	0.00	0.13	0.00	**22.52**
$OECR_{BASE}$	$21,045	$6,888	$14,975	$62,159	$7,694	$31,881	$10,235	$0	$0	$177	$0	**$155,055**
$OECR_{SAMA}$	$21,045	$6,121	$14,975	$62,159	$6,035	$31,881	$10,235	$0	$0	$145	$0	**$152,597**

This information was used as input to the cost-benefit calculation. The results of this calculation are provided in the following table:

SAMA 7 NET VALUE

UNIT	BASE CASE COST-RISK	REVISED COST-RISK	AVERTED COST-RISK
Hope Creek	$19,807,200	$19,480,262	$326,939

Based on a $3,070,000 cost of implementation for HCGS, the net value for this SAMA is -$2,743,062 ($326,939 - $3,070,000), which results in this SAMA not being cost beneficial.

E.6.6 SAMA 8: CONVERT SELECTED FIRE PROTECTION PIPING FROM WET TO DRY PIPE SYSTEM

A corridor outside the control room (and similarly, the lower Control Equipment Room) includes fire protection system equipment. A line rupture could quickly flood the corridor. Since the corridor includes a door that opens to the control room, water could enter the control room if the door should fail. The PRA currently models the probability of operators' failing to secure the fire system locally in order to isolate the leak (FPS-XHE-CRISOL).

This SAMA involves reducing the need for isolating the fire protection header (FPS-XHE-CRISOL). Converting the fire protection piping from wet to dry piping would reduce the need for this operator action. This change requires design changes to the fire protection system to realize the benefit of this SAMA.

Assumptions:

1. For the purposes of this SAMA, it is assumed that operator intervention would still be required to mitigate inadvertent filling of system.

PRA Model Changes to Model SAMA:

The operator action to isolate the fire protection header leak (FPS-XHE-CRISOL) probability was changed from 1.0 to 0.1. This represents the conversion of fire protection from wet to dry pipe system but still requiring operator intervention for inadvertent filling of the system.

Results of SAMA Quantification:

Implementation of this SAMA yielded a small reduction in the CDF, Dose-Risk and Offsite Economic Cost-Risk. The results are summarized in the following table for HCGS:

	CDF	DOSE-RISK	OECR
Base Value	4.44E-06	22.86	$155,055
SAMA Value	4.28E-06	22.55	$152,798
Percent Change	3.7%	1.4%	1.5%

A further breakdown of the Dose-Risk and OECR information is provided in the below table according to release category:

RELEASE CATEGORY	ST1	ST2	ST3	ST4	ST5	ST6	ST7	ST8	ST9	ST10	ST11	TOTAL
$Frequency_{BASE}$	1.83E-07	7.15E-08	1.30E-07	9.70E-07	8.34E-08	3.48E-07	2.16E-07	0.00E+00	2.68E-07	2.39E-07	1.93E-06	**4.44E-06**
$Frequency_{SAMA}$	1.83E-07	6.62E-08	1.30E-07	9.69E-07	6.55E-08	3.48E-07	2.16E-07	0.00E+00	2.32E-07	1.96E-07	1.87E-06	**4.28E-06**
$Dose\text{-}Risk_{BASE}$	3.33	0.99	3.05	8.49	0.92	4.55	1.37	0.00	0.00	0.16	0.00	**22.86**
$Dose\text{-}Risk_{SAMA}$	3.33	0.91	3.05	8.48	0.72	4.55	1.37	0.00	0.00	0.13	0.00	**22.55**
$OECR_{BASE}$	$21,045	$6,888	$14,975	$62,159	$7,694	$31,881	$10,235	$0	$0	$177	$0	**$155,055**
$OECR_{SAMA}$	$21,013	$6,375	$14,975	$62,138	$6,046	$31,881	$10,223	$0	$0	$145	$0	**$152,798**

This information was used as input to the cost-benefit calculation. The results of this calculation are provided in the following table:

SAMA 8 NET VALUE

UNIT	BASE CASE COST-RISK	REVISED COST-RISK	AVERTED COST-RISK
Hope Creek	$19,807,200	$19,505,644	$301,556

Based on a $600,000 cost of implementation for HCGS, the net value for this SAMA is -$298,444 ($301,556 - $600,000), which results in this SAMA not being cost beneficial.

E.6.7 SAMA 10: PROVIDE PROCEDURAL GUIDANCE TO USE B.5.b LOW PRESSURE PUMP FOR NON-SECURITY EVENTS

During certain loss of offsite power scenarios (e.g. SBO resulting in a recirculation seal LOCA) where loss of steam driven high pressure systems is postulated to occur. For these types of scenarios it is desirable to have an independently powered pump for injection into the RPV.

This SAMA involves adding a diesel driven pump that takes suction from outside containment (e.g. CST). This includes improving procedures and adding a new pump.

Assumptions:

1. For the purposes of this SAMA, it is assumed that the procedures and training would change to allow make use of these new injection methods.
2. This alternate injection system would rely upon an independent AC power source (i.e. diesel driven pump).
3. A combined HRA and hardware failure probability of 1E-1 was selected as a screening value for this SAMA.

PRA Model Changes to Model SAMA:

The operator action to align RHRSW to for injection into the RPV probability (RHR-XHE-RHR-INJ) was changed from 1.0E-1 to 1.0E-2. This represents the failure probability of this SAMA modification combined with the nominal operator action failure rate (RHR-XHE-RHR-INJ). The model was requantified with this change. This represents the pump reliability, availability and procedure improvement related to the alternate injection system. No other basic events or fault tree structures were affected.

Results of SAMA Quantification:

Implementation of this SAMA yields a small reduction in the CDF and larger reductions in Dose-Risk and Offsite Economic Cost-Risk. The results are summarized in the following table for HCGS:

	CDF	DOSE-RISK	OECR
Base Value	4.44E-06	22.86	$155,055
SAMA Value	4.39E-06	22.65	$153,467
Percent Change	1.1%	0.9%	1.0%

A further breakdown of the Dose-Risk and OECR information is provided in the below table according to release category:

RELEASE CATEGORY	ST1	ST2	ST3	ST4	ST5	ST6	ST7	ST8	ST9	ST10	ST11	TOTAL
$Frequency_{BASE}$	1.83E-07	7.15E-08	1.30E-07	9.70E-07	8.34E-08	3.48E-07	2.16E-07	0.00E+00	2.68E-07	2.39E-07	1.93E-06	**4.44E-06**
$Frequency_{SAMA}$	1.83E-07	7.15E-08	1.30E-07	9.60E-07	8.34E-08	3.48E-07	1.96E-07	0.00E+00	2.64E-07	2.39E-07	1.92E-06	**4.39E-06**
$Dose\text{-}Risk_{BASE}$	3.33	0.99	3.05	8.49	0.92	4.55	1.37	0.00	0.00	0.16	0.00	**22.86**
$Dose\text{-}Risk_{SAMA}$	3.33	0.99	3.05	8.40	0.92	4.55	1.24	0.00	0.00	0.16	0.00	**22.65**
$OECR_{BASE}$	$21,045	$6,888	$14,975	$62,159	$7,694	$31,881	$10,235	$0	$0	$177	$0	**$155,055**
$OECR_{SAMA}$	$21,045	$6,888	$14,975	$61,519	$7,694	$31,881	$9,288	$0	$0	$177	$0	**$153,467**

This information was used as input to the cost-benefit calculation. The results of this calculation are provided in the following table:

SAMA 10 NET VALUE

UNIT	BASE CASE COST-RISK	REVISED COST-RISK	AVERTED COST-RISK
Hope Creek	$19,807,200	$19,607,622	$199,578

Based on a $100,000 cost of implementation for HCGS, the net value for this SAMA is $99,578 ($199,578 - $100,000), which results in this SAMA being cost beneficial.

E.6.8 SAMA 15: ALTERNATE DESIGN OF CSS SUCTION STRAINER TO MITIGATE PLUGGING

This SAMA involves improving the reliability of the Core Spray suction strainers (CSS-STR-PL-(A thru D)). This would improve Core Spray injection reliability.

<u>Assumptions:</u>

1. For the purposes of this SAMA, this is a hardware change only.
2. This assumes that the reliability of all these strainers is the same.

<u>PRA Model Changes to Model SAMA:</u>

The operator action to open the SW valve(s) locally (CSS-STR-PL-(A thru D)) probability was changed from 8.36E-3 to 8.36E-4. This factor of 10 reduction was applied to all 4 basic events to simulate strainer improved reliability. The model with this change was then requantified to obtain the SAMA CDF value. No other basic events or fault tree structures were affected.

<u>Results of SAMA Quantification:</u>

Implementation of this SAMA yields a small reduction in the CDF and negligible reductions in Dose-Risk and Offsite Economic Cost-Risk. The results are summarized in the following table for HCGS:

	CDF	DOSE-RISK	OECR
Base Value	4.44E-06	22.86	$155,055
SAMA Value	4.33E-06	22.74	$154,166
Percent Change	2.4%	0.5%	0.6%

A further breakdown of the Dose-Risk and OECR information is provided in the below table according to release category:

RELEASE CATEGORY	ST1	ST2	ST3	ST4	ST5	ST6	ST7	ST8	ST9	ST10	ST11	TOTAL
$Frequency_{BASE}$	1.83E-07	7.15E-08	1.30E-07	9.70E-07	8.34E-08	3.48E-07	2.16E-07	0.00E+00	2.68E-07	2.39E-07	1.93E-06	**4.44E-06**
$Frequency_{SAMA}$	1.83E-07	6.94E-08	1.30E-07	9.70E-07	7.61E-08	3.48E-07	2.16E-07	0.00E+00	2.47E-07	2.19E-07	1.88E-06	**4.33E-06**
$Dose\text{-}Risk_{BASE}$	3.33	0.99	3.05	8.49	0.92	4.55	1.37	0.00	0.00	0.16	0.00	**22.86**
$Dose\text{-}Risk_{SAMA}$	3.33	0.96	3.05	8.49	0.84	4.55	1.37	0.00	0.00	0.15	0.00	**22.74**
$OECR_{BASE}$	$21,045	$6,888	$14,975	$62,159	$7,694	$31,881	$10,235	$0	$0	$177	$0	**$155,055**
$OECR_{SAMA}$	$21,045	$6,681	$14,975	$62,159	$7,026	$31,881	$10,235	$0	$0	$162	$0	**$154,166**

This information was used as input to the cost-benefit calculation. The results of this calculation are provided in the following table:

SAMA 15 NET VALUE

UNIT	BASE CASE COST-RISK	REVISED COST-RISK	AVERTED COST-RISK
Hope Creek	$19,807,200	$19,680,797	$126,403

Based on a $1,000,000 cost of implementation for HCGS, the net value for this SAMA is -$873,597 ($126,403 - $1,000,000), which results in this SAMA not being cost beneficial.

E.6.9 SAMA 16: USE OF DIFFERENT DESIGNS FOR SWITCHGEAR ROOM COOLING FANS

This SAMA considers replacing one of four Switchgear room cooling fans (FANS AVH401 through DVH401) with a different design so as to eliminate common cause failure of all fans. An alternate means of cooling could involve multiple portable fans placed strategically in or near the switchgear doorway(s) to provide maximum air flow.

Assumptions:

1. For the purposes of this SAMA, this is a hardware change only.
2. This assumes that the reliablity of all these fans is the same.
3. The replacement fan is assumed to eliminate common cause fan failure for the system

PRA Model Changes to Model SAMA:

All failure to start and failure to run for switchgear room fans common cause events were set to zero. The following table provides a list of the basic events that were set to zero.

SAMA 16 BASIC EVENTS

NAME	DESC
VSW-FAN-FR-DF12	CCF FAILURE FANS A THRU DVH401 FAIL TO RUN
VSW-FAN-FR-DF13	CCF FAILURE FANS A -B AND CVH401 FAIL TO RUN
VSW-FAN-FR-DF14	CCF FAILURE FANS A -B AND DVH401 FAIL TO RUN
VSW-FAN-FR-DF15	CCF FAILURE FANS A -C AND DVH401 FAIL TO RUN
VSW-FAN-FR-DF16	CCF FAILURE FANS B -C AND DVH401 FAIL TO RUN
VSW-FAN-FR-DF17	CCF FAILURE FANS A AND BVH401 FAIL TO RUN
VSW-FAN-FR-DF18	CCF FAILURE FANS A AND CVH401 FAIL TO RUN
VSW-FAN-FR-DF19	CCF FAILURE FANS A AND DVH401 FAIL TO RUN
VSW-FAN-FR-DF20	CCF FAILURE FANS B AND CVH401 FAIL TO RUN
VSW-FAN-FR-DF21	CCF FAILURE FANS B AND DVH401 FAIL TO RUN
VSW-FAN-FR-DF22	CCF FAILURE FANS C AND DVH401 FAIL TO RUN
VSW-FAN-FS-DF01	CCF FAILURE FANS A THRU DVH401 FAIL TO START
VSW-FAN-FS-DF02	CCF FAILURE FANS A -B AND CVH401 FAIL TO START
VSW-FAN-FS-DF03	CCF FAILURE FANS A -B - AND DVH401 FAIL TO START
VSW-FAN-FS-DF04	CCF FAILURE FANS A -C AND DVH401 FAIL TO START
VSW-FAN-FS-DF05	CCF FAILURE FANS B -C AND DVH401 FAIL TO START
VSW-FAN-FS-DF06	CCF FAILURE FANS A AND BVH401 FAIL TO START
VSW-FAN-FS-DF07	CCF FAILURE FANS A AND CVH401 FAIL TO START
VSW-FAN-FS-DF08	CCF FAILURE FANS A AND DVH401 FAIL TO START
VSW-FAN-FS-DF09	CCF FAILURE FANS B AND CVH401 FAIL TO START
VSW-FAN-FS-DF10	CCF FAILURE FANS B AND DVH401 FAIL TO START
VSW-FAN-FS-DF11	CCF FAILURE FANS C AND DVH401 FAIL TO START

No other basic events or fault tree structures were affected.

Results of SAMA Quantification:

Implementation of this SAMA yielded a small reduction in the CDF and negligible reductions in Dose-Risk and Offsite Economic Cost-Risk. The results are summarized in the following table for HCGS:

	CDF	DOSE-RISK	OECR
Base Value	4.44E-06	22.86	$155,055
SAMA Value	4.34E-06	22.73	$154,142
Percent Change	2.4%	0.6%	0.6%

A further breakdown of the Dose-Risk and OECR information is provided in the below table according to release category:

RELEASE CATEGORY	ST1	ST2	ST3	ST4	ST5	ST6	ST7	ST8	ST9	ST10	ST11	TOTAL
$Frequency_{BASE}$	1.83E-07	7.15E-08	1.30E-07	9.70E-07	8.34E-08	3.48E-07	2.16E-07	0.00E+00	2.68E-07	2.39E-07	1.93E-06	**4.44E-06**
$Frequency_{SAMA}$	1.83E-07	6.67E-08	1.30E-07	9.70E-07	7.89E-08	3.48E-07	2.16E-07	0.00E+00	2.56E-07	2.27E-07	1.86E-06	**4.34E-06**
$Dose\text{-}Risk_{BASE}$	3.33	0.99	3.05	8.49	0.92	4.55	1.37	0.00	0.00	0.16	0.00	**22.86**
$Dose\text{-}Risk_{SAMA}$	3.33	0.92	3.05	8.49	0.87	4.55	1.37	0.00	0.00	0.16	0.00	**22.73**
$OECR_{BASE}$	$21,045	$6,888	$14,975	$62,159	$7,694	$31,881	$10,235	$0	$0	$177	$0	**$155,055**
$OECR_{SAMA}$	$21,035	$6,419	$14,975	$62,159	$7,279	$31,881	$10,225	$0	$0	$169	$0	**$154,142**

This information was used as input to the cost-benefit calculation. The results of this calculation are provided in the following table:

SAMA 16 NET VALUE

UNIT	BASE CASE COST-RISK	REVISED COST-RISK	AVERTED COST-RISK
Hope Creek	$19,807,200	$19,678,151	$129,049

Based on a $400,000 cost of implementation for HCGS, the net value for this SAMA is -$270,951 ($129,049 - $400,000), which results in this SAMA not being cost beneficial.

E.6.10 SAMA 17: REPLACE A SUPPLY FAN WITH A DIFFERENT DESIGN IN SERVICE WATER PUMP ROOM

This SAMA considers replacing one of four Service Water Pump Room Supply fans (FANS AV503 through DV503) with a different design so as to eliminate common cause failure of all fans.

Assumptions:

1. For the purposes of this SAMA, this is a hardware change only.
2. This assumes that the reliablity of all these fans is the same.
3. The replacement fan is assumed to eliminate common cause fan failure for the system

PRA Model Changes to Model SAMA:

All failure to start and failure to run for service water pump room supply fans common cause events were set to zero. The following table provides a list of the basic events that were set to zero.

SAMA 17 BASIC EVENTS

NAME	DESC
VIS-FAN-FR-DF01	CCF FAILURE FANS A THRU DV503 FAIL TO RUN
VIS-FAN-FR-DF02	CCF FAILURE FANS A -B AND CV503 FAIL TO RUN
VIS-FAN-FR-DF03	CCF FAILURE FANS A -B AND DV503 FAIL TO RUN
VIS-FAN-FR-DF04	CCF FAILURE FANS A -C AND DV503 FAIL TO RUN
VIS-FAN-FR-DF05	CCF FAILURE FANS B -C AND DV503 FAIL TO RUN
VIS-FAN-FR-DF06	CCF FAILURE FANS A AND BV503 FAIL TO RUN
VIS-FAN-FR-DF07	CCF FAILURE FANS A AND CV503 FAIL TO RUN
VIS-FAN-FR-DF08	CCF FAILURE FANS A AND DV503 FAIL TO RUN
VIS-FAN-FR-DF09	CCF FAILURE FANS B AND CV503 FAIL TO RUN
VIS-FAN-FR-DF10	CCF FAILURE FANS B AND DV503 FAIL TO RUN
VIS-FAN-FR-DF11	CCF FAILURE FANS C AND DV503 FAIL TO RUN
VIS-FAN-FS-DF01	CCF FAILURE FANS A THRU DV503 FAIL TO START
VIS-FAN-FS-DF02	CCF FAILURE FANS A -B AND CV503 FAIL TO START
VIS-FAN-FS-DF03	CCF FAILURE FANS A -B AND DV503 FAIL TO START

SAMA 17 BASIC EVENTS

NAME	DESC
VIS-FAN-FS-DF04	CCF FAILURE FANS A -C AND DV503 FAIL TO START
VIS-FAN-FS-DF05	CCF FAILURE FANS B -C AND DV503 FAIL TO START
VIS-FAN-FS-DF06	CCF FAILURE FANS A AND BV503 FAIL TO START
VIS-FAN-FS-DF07	CCF FAILURE FANS A AND CV503 FAIL TO START
VIS-FAN-FS-DF08	CCF FAILURE FANS A AND DV503 FAIL TO START
VIS-FAN-FS-DF09	CCF FAILURE FANS B AND CV503 FAIL TO START
VIS-FAN-FS-DF10	CCF FAILURE FANS B AND DV503 FAIL TO START
VIS-FAN-FS-DF11	CCF FAILURE FANS C AND DV503 FAIL TO START

No other basic events or fault tree structures were affected.

Results of SAMA Quantification:

Implementation of this SAMA yielded a marginal reduction in the CDF, Dose-Risk and Offsite Economic Cost-Risk. The results are summarized in the following table for HCGS:

	CDF	DOSE-RISK	OECR
Base Value	4.44E-06	22.86	$155,055
SAMA Value	4.21E-06	21.81	$147,407
Percent Change	5.2%	4.6%	4.9%

A further breakdown of the Dose-Risk and OECR information is provided in the below table according to release category:

RELEASE CATEGORY	ST1	ST2	ST3	ST4	ST5	ST6	ST7	ST8	ST9	ST10	ST11	TOTAL
$Frequency_{BASE}$	1.83E-07	7.15E-08	1.30E-07	9.70E-07	8.34E-08	3.48E-07	2.16E-07	0.00E+00	2.68E-07	2.39E-07	1.93E-06	**4.44E-06**
$Frequency_{SAMA}$	1.83E-07	7.12E-08	1.30E-07	8.65E-07	8.25E-08	3.48E-07	2.00E-07	0.00E+00	2.55E-07	2.30E-07	1.85E-06	**4.21E-06**
$Dose\text{-}Risk_{BASE}$	3.33	0.99	3.05	8.49	0.92	4.55	1.37	0.00	0.00	0.16	0.00	**22.86**
$Dose\text{-}Risk_{SAMA}$	3.33	0.98	3.05	7.57	0.91	4.55	1.27	0.00	0.00	0.16	0.00	**21.81**
$OECR_{BASE}$	$21,045	$6,888	$14,975	$62,159	$7,694	$31,881	$10,235	$0	$0	$177	$0	**$155,055**
$OECR_{SAMA}$	$21,045	$6,855	$14,975	$55,432	$7,611	$31,876	$9,443	$0	$0	$170	$0	**$147,407**

This information was used as input to the cost-benefit calculation. The results of this calculation are provided in the following table:

SAMA 17 NET VALUE

UNIT	BASE CASE COST-RISK	REVISED COST-RISK	AVERTED COST-RISK
Hope Creek	$19,807,200	$18,843,754	$963,446

Based on a $600,000 cost of implementation for HCGS, the net value for this SAMA is $363,446 ($963,446 - $600,000), which results in this SAMA being cost beneficial.

E.6.11 SAMA 18: REPLACE A RETURN FAN WITH A DIFFERENT DESIGN IN SERVICE WATER PUMP ROOM

This SAMA considers replacing one of four Service Water Pump Room Return fans (FANS AV504 through DV504) with a different design so as to eliminate common cause failure of all fans.

Assumptions:

1. For the purposes of this SAMA, this is a hardware change only.
2. This assumes that the reliablity of all these fans are the same.
3. The replacement fan is assumed to eliminate common cause fan failure for the system

PRA Model Changes to Model SAMA:

All Service Water Pump Room Return fan's failure to start and failure to run common cause events were set to zero. The following table provides a list of the basic events that were set to zero.

SAMA 18 BASIC EVENTS

NAME	DESC
VIS-FAN-FR-DF12	CCF FAILURE FANS A THRU DV504 FAIL TO RUN
VIS-FAN-FR-DF13	CCF FAILURE FANS A -B AND CV504 FAIL TO RUN
VIS-FAN-FR-DF14	CCF FAILURE FANS A -B AND DV504 FAIL TO RUN
VIS-FAN-FR-DF15	CCF FAILURE FANS A -C AND DV504 FAIL TO RUN
VIS-FAN-FR-DF16	CCF FAILURE FANS B -C AND DV504 FAIL TO RUN
VIS-FAN-FR-DF17	CCF FAILURE FANS A AND BV504 FAIL TO RUN
VIS-FAN-FR-DF18	CCF FAILURE FANS A AND CV504 FAIL TO RUN

SAMA 18 BASIC EVENTS

NAME	DESC
VIS-FAN-FR-DF19	CCF FAILURE FANS A AND DV504 FAIL TO RUN
VIS-FAN-FR-DF20	CCF FAILURE FANS B AND CV504 FAIL TO RUN
VIS-FAN-FR-DF21	CCF FAILURE FANS B AND DV504 FAIL TO RUN
VIS-FAN-FR-DF22	CCF FAILURE FANS C AND DV504 FAIL TO RUN
VIS-FAN-FS-DF12	CCF FAILURE FANS A THRU DV504 FAIL TO START
VIS-FAN-FS-DF13	CCF FAILURE FANS A -B ANDCV504 FAIL TO START
VIS-FAN-FS-DF14	CCF FAILURE FANS A -B AND DV504 FAIL TO START
VIS-FAN-FS-DF15	CCF FAILURE FANS A -C AND DV504 FAIL TO START
VIS-FAN-FS-DF16	CCF FAILURE FANS B -C AND DV504 FAIL TO START
VIS-FAN-FS-DF17	CCF FAILURE FANS A AND BV504 FAIL TO START
VIS-FAN-FS-DF18	CCF FAILURE FANS A AND CV504 FAIL TO START
VIS-FAN-FS-DF19	CCF FAILURE FANS A AND DV504 FAIL TO START
VIS-FAN-FS-DF20	CCF FAILURE FANS B AND CV504 FAIL TO START
VIS-FAN-FS-DF21	CCF FAILURE FANS B AND DV504 FAIL TO START
VIS-FAN-FS-DF22	CCF FAILURE FANS C AND DV504 FAIL TO START

No other basic events or fault tree structures were affected.

Results of SAMA Quantification:

Implementation of this SAMA yielded a marginal reduction in the CDF, Dose-Risk and Offsite Economic Cost-Risk. The results are summarized in the following table for HCGS:

	CDF	DOSE-RISK	OECR
Base Value	4.44E-06	22.86	$155,055
SAMA Value	4.21E-06	21.81	$147,407
Percent Change	5.2%	4.6%	4.9%

A further breakdown of the Dose-Risk and OECR information is provided in the below table according to release category:

RELEASE CATEGORY	ST1	ST2	ST3	ST4	ST5	ST6	ST7	ST8	ST9	ST10	ST11	TOTAL

RELEASE CATEGORY	ST1	ST2	ST3	ST4	ST5	ST6	ST7	ST8	ST9	ST10	ST11	TOTAL
$Frequency_{BASE}$	1.83E-07	7.15E-08	1.30E-07	9.70E-07	8.34E-08	3.48E-07	2.16E-07	0.00E+00	2.68E-07	2.39E-07	1.93E-06	**4.44E-06**
$Frequency_{SAMA}$	1.83E-07	7.12E-08	1.30E-07	8.65E-07	8.25E-08	3.48E-07	2.00E-07	0.00E+00	2.55E-07	2.30E-07	1.85E-06	**4.21E-06**
$Dose\text{-}Risk_{BASE}$	3.33	0.99	3.05	8.49	0.92	4.55	1.37	0.00	0.00	0.16	0.00	**22.86**
$Dose\text{-}Risk_{SAMA}$	3.33	0.98	3.05	7.57	0.91	4.55	1.27	0.00	0.00	0.16	0.00	**21.81**
$OECR_{BASE}$	$21,045	$6,888	$14,975	$62,159	$7,694	$31,881	$10,235	$0	$0	$177	$0	**$155,055**
$OECR_{SAMA}$	$21,045	$6,855	$14,975	$55,432	$7,611	$31,876	$9,443	$0	$0	$170	$0	**$147,407**

This information was used as input to the cost-benefit calculation. The results of this calculation are provided in the following table:

SAMA 18 NET VALUE

UNIT	BASE CASE COST-RISK	REVISED COST-RISK	AVERTED COST-RISK
Hope Creek	$19,807,200	$18,843,754	$963,446

Based on a $600,000 cost of implementation for HCGS, the net value for this SAMA is $363,446 ($963,446 - $600,000), which results in this SAMA being cost beneficial.

E.6.12 SAMA 30 PROVIDE PROCEDURAL GUIDANCE FOR PARTIAL TRANSFER OF CONTROL FUNCTIONS FROM CONTROL ROOM TO THE REMOTE SHUTDOWN PANEL

SAMAs 30 through 35 address fire-related scenarios from the external events analysis. Although the methodology delineated below deals with specific events associated with the Remote Shutdown Panel (RSP), it has been applied to all fire SAMAs.

Human performance associated with the RSP accounts for a significant contribution to fire CDF at HCGS. For fires that cause catastrophic damage to the controls of a single critical system, the reliability of controling the plant may be improved by allowing the operators to transfer only a single division of controls to the RSP to recover a channel of the critical system while the MCR is maintained as the primary control center. A permutaiton of this SAMA would be to use local system controls rather than the RSP.

It is assumed that if the portion of the HCGS CDF and release consequences related to RSP operator reliability can be identified, then an averted cost-risk can be calculated for this SAMA. The steps used to perform this calculation are provided below:

- Determine the component of the total MACR attributable to external events
- Determine the component of the external events cost-risk attributable to fire events
- Determine the component of the fire-based cost-risk attributable to RSP operator reliability
- Calculate the percent reduction in fire CDF that would occur for the RSP if the SAMA is implemented and reduce the cost-risk for the RSP by the same percent. The reduction in cost-risk is the averted cost-risk for this SAMA.

The baseline assumption for external events contributions in the HCGS SAMA is that they are a little more than 5 times the internal events contributions (see Section 4.6). Given that the internal events contribution to the MACR is $3,144,000, a value of $16,663,200 is assigned to external events.

The relative contribution of fire events to the total external events CDF can be estimated in several ways, but the process established in Section 5.1.7 to calculate the fire-based contributions for the SAMAs requiring PRA model quantification is considered to be appropriate for HCGS and is used here. The fire contribution to the MACR is therefore $12,319,700.

The cost-risk associated with each fire area can then be determined based on their relative contributions to the total fire CDF and the assumption that the CDF is proportional to cost-risk (fire CDFs are provided in Section D.5.1.7.1):

BASIC EVENT ID	PERCENT OF FIRE RISK	CORRESPONDING COST-RISK
%IE-FIRE03	30.5%	$3,754,488
%IE-FIRE02	25.4%	$3,128,740
%IE-FIRE01	21.8%	$2,681,777

The risk reduction possible for each of these areas is a fraction of the total based on the potential capabilities of the changes proposed in this SAMA. Based on the large cost-risk contributions from these fire compartments, and the fact this SAMA involves maintaining MCR habitability (and thereby improving operator reliability) via revised fire procedures , it was assumed that this SAMA eliminates as much as 90% of the risk associated with these compartments to simplify the calculations. The cost-risk calculation for this SAMA is straightforward and is equal to 0.90 times the total cost-risk from the fire compartments, or $8,600,000 after rounding.

SAMA 30 NET VALUE

COST OF IMPLEMENTATION	TOTAL AVERTED COST-RISK	NET VALUE
$100,000	$8,600,000	$8,500,000

Based on a $100,000 cost of implementation for HCGS, the net value for this SAMA is $8,500,000 ($8,600,000 - $100,000), which results in this SAMA being cost beneficial.

E.6.13 SAMA 31 INSTALL IMPROVED FIRE BARRIERS IN THE MCR CONTROL CABINETS CONTAINING THE PRIMARY MSIV CONTROL CIRCUITS

MCR fires that propagate from the originating cabinets result in widespread control damage and induce environmental conditions that would require abandonment even if the controls were not damaged. IPEEE insights suggest that improving the fire barriers in the console containing the primary MSIV controls would reduce the probability of these types of fire events.

BASIC EVENT ID	PERCENT OF FIRE RISK	CORRESPONDING COST-RISK
%IE-FIRE06	2.9%	$361,827

The risk reduction possible for this area is a fraction of the total based on the potential capabilities of the changes proposed in this SAMA. Based on the nominal cost-risk contribution associated with this fire compartment, and the fact this SAMA involves a substantial hardware modification, it was assumed that this SAMA eliminates 100% of the risk associated with this compartment to simplify the calculations. The cost-risk calculation for this SAMA is straightforward and is equal to 1.0 times the total cost-risk from the fire compartments, or $360,000 after rounding.

SAMA 31 NET VALUE

COST OF IMPLEMENTATION	TOTAL AVERTED COST-RISK	NET VALUE
$1,200,000	$360,000	-$840,000

Based on a $1,200,000 cost of implementation for HCGS, the net value for this SAMA is -$840,000 ($360,000 - $1,200,000), which results in this SAMA not being cost beneficial.

E.6.14 SAMA 32 INSTALL ADDITIONAL PHYSICAL BARRIERS TO LIMIT DISPERSION OF FUEL OIL FROM DG ROOMS

For compartment 5339 fire scenario 5339_2, install a curb or a diversion channel to ensure liquids from the DG rooms cannot communicate with Room 5339.

BASIC EVENT ID	PERCENT OF FIRE RISK	CORRESPONDING COST-RISK
%IE-FIRE28	4.3%	$532,099

The risk reduction possible for this area is a fraction of the total based on the potential capabilities of the changes proposed in this SAMA. Due to the small cost-risk contributions from this fire compartment, and the fact this SAMA involves a hardware modification, it was conservatively assumed that this SAMA eliminates 90% of the risk associated with this compartment to simplify the calculations. The cost-risk calculation for this SAMA is straightforward and is equal to 0.90 times the total cost-risk from the fire compartment, or $480,000 after rounding.

SAMA 32 NET VALUE

COST OF IMPLEMENTATION	TOTAL AVERTED COST-RISK	NET VALUE
$800,000	$480,000	-$320,000

Based on a $800,000 cost of implementation for HCGS, the net value for this SAMA is -$320,000 ($480,000 - $800,000), which results in this SAMA not being cost beneficial.

E.6.15 SAMA 33 INSTALL DIVISION II 480VAC BUS CROSSTIES

For DG room (D) fire scenario 5304_2, install cross-ties between the Division II 480VAC buses (potentially 10B420 to10B480 and 10B460 to 10B440).

BASIC EVENT ID	PERCENT OF FIRE RISK	CORRESPONDING COST-RISK
%IE-FIRE37	4.0%	$495,206

The risk reduction possible for this area is a fraction of the total based on the potential capabilities of the changes proposed in this SAMA. Due to the small cost-risk contributions from this fire compartment, and the fact this SAMA involves a hardware modification, it was conservatively assumed that this SAMA eliminates 90% of the risk associated with this compartment to simplify the calculations. The cost-risk calculation for this SAMA is straightforward and is equal to 0.90 times the total cost-risk from the fire compartment, or $370,000 after rounding.

These model changes do not account for any negative risk factors associated with implementation of an AC cross-tie, such as failing to isolate a fault before completing the cross-tie or improperly placing two separate divisions in parallel during power operation. Excluding these factors inflates the averted cost-risk for the SAMA; however, the effects are considered to be small relative to the reduction in risk associated with implementation.

SAMA 33 NET VALUE

COST OF IMPLEMENTATION	TOTAL AVERTED COST-RISK	NET VALUE
$1,320,000	$450,000	-$870,000

Based on a $1,320,000 cost of implementation for HCGS, the net value for this SAMA is -$870,000 ($450,000 - $1,320,000), which results in this SAMA <u>not</u> being cost beneficial.

E.6.16 SAMA 34 INSTALL DIVISION I 480VAC BUS CROSSTIES

For DG room (C) fire scenario 5306_2, install cross-ties between the Division I 480VAC buses (potentially 10B410 to10B430 and 10B450 to 10B470).

BASIC EVENT ID	PERCENT OF FIRE RISK	CORRESPONDING COST-RISK
%IE-FIRE20	3.8%	$473,312

The risk reduction possible for this area is a fraction of the total based on the potential capabilities of the changes proposed in this SAMA. Due to the small cost-risk contributions from this fire compartment, and the fact this SAMA involves a hardware modification, it was conservatively assumed that this SAMA eliminates 90% of the risk associated with this compartment to simplify the calculations. The cost-risk calculation for this SAMA is straightforward and is equal to 0.90 times the total cost-risk from the fire compartment, or $430,000 after rounding.

These model changes do not account for any negative risk factors associated with implementation of an AC cross-tie, such as failing to isolate a fault before completing the cross-tie or improperly placing two separate divisions in parallel during power operation. Excluding these factors inflates the averted cost-risk for the SAMA; however, the effects are considered to be small relative to the reduction in risk associated with implementation.

SAMA 34 NET VALUE

COST OF IMPLEMENTATION	TOTAL AVERTED COST-RISK	NET VALUE
$1,320,000	$430,000	-$890,000

Based on a $1,320,000 cost of implementation for HCGS, the net value for this SAMA is -$890,000 ($430,000 - $1,320,000), which results in this SAMA <u>not</u> being cost beneficial.

E.6.17 SAMA 35 RELOCATE, MINIMIZE AND/OR ELIMINATE ELECTRICAL HEATERS IN ELECTRICAL ACCESS ROOM

For compartment 3425/5401 fire scenario 5401_1, move or eliminate the electrical heaters in the electrical access room (Aux Building 124’ level) to prevent damage to the Division II power cables.

BASIC EVENT ID	PERCENT OF FIRE RISK	CORRESPONDING COST-RISK
%IE-FIRE38	3.4%	$414,895

The risk reduction possible for this area is a fraction of the total based on the potential capabilities of the changes proposed in this SAMA. Due to the small cost-risk contributions from this fire compartment, and the fact this SAMA involves elimination of the risk condition, it was conservatively assumed that this SAMA eliminates 99% of the risk associated with this compartment to simplify the calculations. The cost-risk calculation for this SAMA is straightforward and is equal to 0.99 times the total cost-risk from the fire compartment, or $340,000 after rounding.

SAMA 35 NET VALUE

COST OF IMPLEMENTATION	TOTAL AVERTED COST-RISK	NET VALUE
$270,000	$370,000	$100,000

Based on a $270,000 cost of implementation for HCGS, the net value for this SAMA is $100,000 ($370,000 - $270,000), which results in this SAMA being cost beneficial.

E.6.18 SAMA 36 PROVIDE PROCEDURAL GUIDANCE FOR LOSS OF ALL 1E 120VAC POWER

SAMAs 36, 37 and 38 address seismic-induced scenarios from the external events analysis. The same methodology utilized for fire SAMAs (30 through 35) is applied here. The only notable exception is the seismic contribution to the MACR is much less than that for fire, and calculated to be $794,644 (see Section 5.7.1).

For Seismic-Induced Equipment Damage State SET-36 (Impacts - 120V PNL481), develop MCR procedures to operate the plant after a loss of all class 1E 120V AC power.

BASIC EVENT ID	PERCENT OF SEISMIC RISK	CORRESPONDING COST-RISK
%IE-SET36	59.8%	$475,341

The risk reduction possible for this scenario is a fraction of the total based on the potential capabilities of the changes proposed in this SAMA. Due to the large cost-risk contributions from this scenario, and the fact this SAMA involves improving operator reliability, it was conservatively assumed that this SAMA eliminates 50% of the risk associated with this seismic event to simplify the calculations. The cost-risk calculation for this SAMA is straightforward and is equal to 0.50 times the total cost-risk from the fire compartment, or $200,000 after rounding.

SAMA 36 NET VALUE

COST OF IMPLEMENTATION	TOTAL AVERTED COST-RISK	NET VALUE
$270,000	$240,000	-$30,000

Based on a $270,000 cost of implementation for HCGS, the net value for this SAMA is -$30,000 ($240,000- $270,000), which results in this SAMA not being cost beneficial.

E.6.19 SAMA 37 REINFORCE 1E 120V AC DISTRIBUTION PANELS

For Seismic-Induced Equipment Damage State SET-36 (Impacts - 120V PNL481), reinforce the class 1E 120V AC distribution panels.

BASIC EVENT ID	PERCENT OF SEISMIC RISK	CORRESPONDING COST-RISK
%IE-SET36	59.8%	$475,341

The risk reduction possible for this scenario is a fraction of the total based on the potential capabilities of the changes proposed in this SAMA. Due to the large cost-risk contributions from this scenario, and the fact this SAMA involves a hardware modification, it was conservatively assumed that this SAMA eliminates 90% of the risk associated with this seismic event to simplify the calculations. The cost-risk calculation for this SAMA is straightforward and is equal to 0.90 times the total cost-risk from the fire compartment, or $360,000 after rounding.

SAMA 37 NET VALUE

COST OF IMPLEMENTATION	TOTAL AVERTED COST-RISK	NET VALUE
$500,000	$430,000	-$70,000

Based on a $500,000 cost of implementation for HCGS, the net value for this SAMA is -$70,000 ($430,000 - $500,000), which results in this SAMA not being cost beneficial.

E.6.20 SAMA 39 PROVIDE PROCEDURAL GUIDANCE TO BYPASS RCIC TURBINE EXHAUST PRESSURE TRIP

Revise procedure to allow bypass of RCIC turbine exhaust pressure trip.

This SAMA was generated as a result of the industry SAMA list review and upon detailed review by the PRA group, was considered to be applicabile to HCGS.

Results of SAMA Quantification:

Implementation of this SAMA yields a marginal reduction in the CDF, Dose-Risk and Offsite Economic Cost-Risk. The results are summarized in the following table for HCGS:

	CDF	DOSE-RISK	OECR
Base Value	4.44E-06	22.86	$155,055
SAMA Value	4.01E-06	22.79	$154,593
Percent Change	9.8%	0.3%	0.3%

A further breakdown of the Dose-Risk and OECR information is provided in the below table according to release category:

RELEASE CATEGORY	ST1	ST2	ST3	ST4	ST5	ST6	ST7	ST8	ST9	ST10	ST11	TOTAL
$Frequency_{BASE}$	1.83E-07	7.15E-08	1.30E-07	9.70E-07	8.34E-08	3.48E-07	2.16E-07	0.00E+00	2.68E-07	2.39E-07	1.93E-06	**4.44E-06**
$Frequency_{SAMA}$	1.81E-07	7.15E-08	1.30E-07	9.70E-07	8.09E-08	3.48E-07	2.16E-07	0.00E+00	2.52E-07	2.29E-07	1.53E-06	**4.01E-06**
$Dose\text{-}Risk_{BASE}$	3.33	0.99	3.05	8.49	0.92	4.55	1.37	0.00	0.00	0.16	0.00	**22.86**
$Dose\text{-}Risk_{SAMA}$	3.29	0.99	3.04	8.49	0.89	4.56	1.37	0.00	0.00	0.16	0.00	**22.79**
$OECR_{BASE}$	$21,045	$6,888	$14,975	$62,159	$7,694	$31,881	$10,235	$0	$0	$177	$0	**$155,055**
$OECR_{SAMA}$	$20,815	$6,885	$14,950	$62,177	$7,467	$31,912	$10,217	$0	$0	$170	$0	**$154,593**

This information was used as input to the cost-benefit calculation. The results of this calculation are provided in the following table:

SAMA 39 NET VALUE

UNIT	BASE CASE COST-RISK	REVISED COST-RISK	AVERTED COST-RISK
Hope Creek	$19,807,200	$19,673,514	$133,686

Based on a $120,000 cost of implementation for HCGS, the net value for this SAMA is $13,686 ($133,686 - $120,000), which results in this SAMA being (marginally) cost beneficial.

E.6.21 SAMA 40 INCREASE RELIABILITY / INSTALL MANUAL BYPASS OF LP PERMISSIVE

Increase the reliability of the low pressure ECCS RPV low pressure permissive circuitry. Install manual bypass of low pressure permissive.

This SAMA was generated as a result of the industry SAMA list review and upon detailed review by the PRA group, was considered to be applicabile to HCGS.

<u>Results of SAMA Quantification:</u>

Implementation of this SAMA yields a marginal reduction in the CDF, Dose-Risk and Offsite Economic Cost-Risk. The results are summarized in the following table for HCGS:

	CDF	DOSE-RISK	OECR
Base Value	4.44E-06	22.86	$155,055
SAMA Value	4.38E-06	22.63	$153,373
Percent Change	1.4%	1.0%	1.1%

A further breakdown of the Dose-Risk and OECR information is provided in the below table according to release category:

RELEASE CATEGORY	ST1	ST2	ST3	ST4	ST5	ST6	ST7	ST8	ST9	ST10	ST11	TOTAL
$Frequency_{BASE}$	1.83E-07	7.15E-08	1.30E-07	9.70E-07	8.34E-08	3.48E-07	2.16E-07	0.00E+00	2.68E-07	2.39E-07	1.93E-06	**4.44E-06**
$Frequency_{SAMA}$	1.83E-07	7.13E-08	1.30E-07	9.48E-07	8.26E-08	3.46E-07	2.16E-07	0.00E+00	2.65E-07	2.37E-07	1.90E-06	**4.38E-06**
$Dose\text{-}Risk_{BASE}$	3.33	0.99	3.05	8.49	0.92	4.55	1.37	0.00	0.00	0.16	0.00	**22.86**
$Dose\text{-}Risk_{SAMA}$	3.33	0.98	3.04	8.30	0.91	4.53	1.37	0.00	0.00	0.16	0.00	**22.63**
$OECR_{BASE}$	$21,045	$6,888	$14,975	$62,159	$7,694	$31,881	$10,235	$0	$0	$177	$0	**$155,055**
$OECR_{SAMA}$	$21,045	$6,866	$14,950	$60,767	$7,624	$31,728	$10,217	$0	$0	$176	$0	**$153,373**

This information was used as input to the cost-benefit calculation. The results of this calculation are provided in the following table:

SAMA 40 NET VALUE

UNIT	BASE CASE COST-RISK	REVISED COST-RISK	AVERTED COST-RISK
Hope Creek	$19,807,200	$19,592,698	$214,502

Based on a $620,000 cost of implementation for HCGS, the net value for this SAMA is -$405,498 ($214,502 - $620,000), which results in this SAMA not being cost beneficial.

E.6.22 SUMMARY

All of the SAMAs reviewed showed at least some benefit with respect to the traditional CDF and LERF risk metrics. Nearly half of the proposed SAMAs are nominally cost beneficial when comparing the averted cost-risk to their implementation costs.

Based on the given implementation costs, a list of those cost-beneficial SAMAs at the nominal level is given below that show the most likely candidates for proposed implementation. They are listed as follows:

SAMA 1: Remove ADS Inhibit from Non-ATWS Emergency Operating Procedures

SAMA 3: Install Back-Up Air Compressor to Supply AOVs

SAMA 4: Provide Procedural Guidance to Cross-Tie RHR Trains

SAMA 10: Provide Procedural Guidance to Use B.5.b Low Pressure Pump for Non-Security Events

SAMA 17: Replace a Supply Fan with a Different Design in Service Water Pump Room

SAMA 18: Replace a Return Fan with a Different Design in Service Water Pump Room

SAMA 30: Provide Procedural Guidance for Partial Transfer of Control Functions from the Control Room to the Remote Shutdown Panel

SAMA 35: Relocate, Minimize, and/or Eliminate Electrical Heaters in Electrical Access Room

SAMA 39: Provide Procedural Guidance to Bypass RCIC Turbine Exhaust Pressure Trip

E.7 UNCERTAINTY ANALYSIS

The following three uncertainties were further investigated as to their impact on the overall SAMA evaluation:

- Use a discount rate of 7 percent, instead of 3 percent used in the base case analysis.
- Use the 95th percentile PRA results in place of the mean PRA results.
- Selected MACCS2 input variables.

E.7.1 REAL DISCOUNT RATE

A sensitivity study has been performed in order to identify how the conclusions of the SAMA analysis might change based on the value assigned to the real discount rate (RDR). The original RDR of 3 percent, which could be viewed as conservative, has been changed to 7 percent and the modified maximum averted cost-risk was re-calculated using the methodology outlined in Section E.4.

Phase 1 SAMAs are not impacted by use of the 7 percent RDR. Refer to Section E.5 and Table E.5-3 for a detailed analysis of each Phase 1 SAMA that was screened from further analysis.

The Phase 2 analysis was re-performed using the 7 percent RDR. Implementation of the 7 percent RDR reduced the MMACR by 28 percent compared with the case where a 3 percent RDR was used. This corresponds to a decrease in the MMACR from $19,807,200 to $14,263,200.

The Phase 2 SAMAs are dispositioned based on PRA insights or detailed analysis. All of the PRA insights used to screen the SAMAs are still applicable given the use of the 7 percent real discount rate as the change only strengthens the factors used to screen them. The SAMA candidates screened based on these insights are considered to be addressed and are not further investigated.

The remaining Phase 2 SAMAs were dispositioned based on the results of a SAMA specific cost-benefit analysis. This step has been re-performed using the 7 percent real discount rate to calculate the net values for the SAMAs.

As shown below, the determination of cost effectiveness changed for only one of the Phase 2 SAMAs (SAMA 39) when the 7 percent RDR was used in lieu of 3 percent.

SUMMARY OF THE IMPACT OF THE RDR VALUE ON THE DETAILED SAMA ANALYSES

SAMA ID	COST OF IMPLEMENTATION	AVERTED COST RISK (3 PERCENT RDR)	NET VALUE (3 PERCENT RDR)	AVERTED COST RISK (7 PERCENT RDR)	NET VALUE (7 PERCENT RDR)	CHANGE IN COST EFFECTIVENESS?
1	$200,000	$5,267,619	$5,067,619	$3,792,915	$3,592,915	No
3	$700,000	$3,302,145	$2,602,145	$2,377,626	$1,677,626	No
4	$100,000	$4,358,126	$4,258,126	$3,129,878	$3,029,878	No
5	$2,050,000	$704,548	($1,345,452)	$511,043	($1,538,957)	No
7	$3,070,000	$326,939	($2,743,062)	$237,397	($2,832,603)	No
8	$600,000	$301,556	($298,444)	$219,108	($380,892)	No
10	$100,000	$199,578	$99,578	$143,791	$43,791	No
15	$1,000,000	$126,403	($873,597)	$92,604	($907,396)	No
16	$400,000	$129,049	($270,951)	$94,443	($305,557)	No
17	$600,000	$963,446	$363,446	$694,090	$94,090	No
18	$600,000	$963,446	$363,446	$694,090	$94,090	No
30	$100,000	$8,600,000	$8,500,000	$6,200,000	$6,100,000	No
31	$1,200,000	$360,000	($840,000)	$260,000	($940,000)	No
32	$800,000	$480,000	($320,000)	$340,000	($460,000)	No
33	$1,320,000	$450,000	($870,000)	$320,000	($1,000,000)	No
34	$1,320,000	$430,000	($890,000)	$310,000	($1,010,000)	No
35	$270,000	$370,000	$100,000	$270,000	$0	No
36	$270,000	$240,000	($30,000)	$170,000	($100,000)	No
37	$500,000	$430,000	($70,000)	$310,000	($190,000)	No
39	$120,000	$133,686	$13,686	$104,328	($15,672)	Yes
40	$620,000	$214,502	($405,498)	$154,766	($465,234)	No

E.7.2 95TH PERCENTILE PRA RESULTS

The results of the SAMA analysis can be impacted by implementing conservative values from the PRA's uncertainty distribution. If the best estimate failure probability values were consistently lower than the "actual" failure probabilities, the PRA model would underestimate plant risk and yield lower than "actual" averted cost-risk values for potential SAMAs. Re-assessing the cost-benefit calculations using the high end of the failure probability distributions is a means of identifying the impact of having consistently underestimated failure probabilities for plant equipment and operator actions included in the PRA model.

A Level 1 internal events model uncertainty analysis was performed for HCGS. The availability and use of Level 2 uncertainties is unique since most plants incorporate only Level 1 analyses in their SAMA reports. The reason Level 2 analyses are not typically used is due to the differing degree of development and uncertainties between the two models. Specifically, the Level 1 model tends to represent the plant in a more thorough and comprehensive manner as opposed to the Level 2 model. Furthermore, there are more release contributors beyond those captured by LERF. As such, for the purposes of the 95th percentile analysis, only Level 1 results are used in the uncertainty process. The results of the Level 1 calculation are provided below.

In performing the sensitivity analysis, only the base case was used in determining the appropriate value for the 95th percentile. For those SAMAs that required the addition of new basic events, no new uncertainty distributions were assigned since the design and implementation of each SAMA was arbitrary and was defined by the analysis assumptions. The results of this uncertainty analysis, therefore, show the expected statistical uncertainty of the CDF risk metrics under the assumption that each SAMA was designed and implemented as it was specified in this analysis. The analysis was run using the EPRI R&R Workstation UNCERT code (version 2.2) with the following simulation settings:

- Sample size - 25,000 trials
- Random seed - AUTO
- Sampling method - Monte Carlo

The calculational results of this uncertainty calculation is shown in the below table. The term CDF_{pe} refers to the nominal CDF point estimate of 4.44E-06.

SUMMARY OF UNCERTAINTY DISTRIBUTION

MEAN	5%	50%	95%	FACTOR > CDF_{PE}	STD DEV
5.41E-06	1.91E-06	3.85E-06	1.26E-05	2.84	8.77E-06

The above table reveals a factor that is 2.84 greater than the respective point estimate CDF, which is in agreement with industry experience. Therefore, for this analysis, the 95th percentile for the base case is used to examine the change in the cost benefit for each SAMA.

E.7.2.1 PHASE 1 IMPACT

Phase 1 SAMAs are not impacted by use of the 95th percentile PRA results. The Phase 1 screening process involved qualitative disposition of (2) SAMAs, and hence, no PRA requantification data was necessary for these SAMAs. Refer to Table E.5-3 for a discussion of each Phase 1 SAMA that was screened from further analysis. It is not necessary to perform any sensitivity analysis on these (2) SAMAs. All other Phase 1 SAMAs transitioned to the Phase 2 analysis and were subject to the sensitivity analyses in the following sections.

E.7.2.2 PHASE 2 IMPACT

As discussed above, a single factor based on the 95th percentile for the base case is used to determine the impact of the cost-benefit analysis for the proposed SAMA candidates. The uncertainty analyses that are available for the Level 1 model are not available (or not used) for the Level 2 and 3 PRA models. In order to simulate the use of the 95th percentile results for the Level 2 and 3 models, the same scaling factor calculated for the Level 1 results was implicitly applied to the Level 2 and 3 models.

The Phase 2 SAMA list was re-examined by multiplying the nominal averted cost risk by the ratio of the 95th percentile to the nominal CDF value (see Section 7.2) to identify SAMAs that would be re-characterized as cost beneficial, i.e., positive net value. Those SAMAs that were previously determined to be not cost beneficial due to implementation costs exceeding their associated nominal averted cost risk may be potentially cost beneficial at the revised 95th percentile averted cost risk. In this case, four additional Phase 2 SAMAs become cost beneficial.

As explained in Section E.7.2.1 above, no Phase 1 SAMAs were retained in the Phase 2 analysis when utilizing the 95th percentile PRA results, since these SAMAs were dispositioned independently of implementation cost.

E.7.2.3 95TH PERCENTILE SUMMARY

The following table provides a summary of the impact of using the 95th percentile PRA results on the detailed cost-benefit calculations that have been performed.

SUMMARY OF THE IMPACT OF USING THE 95TH PERCENTILE PRA RESULTS

SAMA ID	COST OF IMPLEMENTATION	AVERTED COST RISK (BASE)	NET VALUE (BASE)	AVERTED COST RISK (95TH PERCENTILE)	NET VALUE (95TH PERCENTILE)	CHANGE IN COST EFFECTIVE-NESS?
1	$200,000	$5,267,619	$5,067,619	$14,943,264	$14,743,264	No
3	$700,000	$3,302,145	$2,602,145	$9,367,576	$8,667,576	No
4	$100,000	$4,358,126	$4,258,126	$12,363,199	$12,263,199	No
5	$2,050,000	$704,548	($1,345,452)	$1,998,672	($51,328)	No
7	$3,070,000	$326,939	($2,743,062)	$927,464	($2,142,536)	No
8	$600,000	$301,556	($298,444)	$855,458	$255,458	Yes
10	$100,000	$199,578	$99,578	$566,165	$466,165	No
15	$1,000,000	$126,403	($873,597)	$358,583	($641,417)	No
16	$400,000	$129,049	($270,951)	$366,089	($33,911)	No
17	$600,000	$963,446	$363,446	$2,733,120	$2,133,120	No
18	$600,000	$963,446	$363,446	$2,733,120	$2,133,120	No
30	$100,000	$8,600,000	$8,500,000	$24,396,614	$24,296,614	No
31	$1,200,000	$360,000	($840,000)	$1,021,254	($178,746)	No
32	$800,000	$480,000	($320,000)	$1,361,671	$561,671	Yes
33	$1,320,000	$450,000	($870,000)	$1,276,567	($43,433)	No
34	$1,320,000	$430,000	($890,000)	$1,219,831	($100,169)	No
35	$270,000	$370,000	$100,000	$1,049,622	$779,622	No
36	$270,000	$240,000	($30,000)	$680,836	$410,836	Yes
37	$500,000	$430,000	($70,000)	$1,219,831	$719,831	Yes
39	$120,000	$133,686	$13,686	$379,243	$259,243	No

SUMMARY OF THE IMPACT OF USING THE 95TH PERCENTILE PRA RESULTS

SAMA ID	COST OF IMPLEMENTATION	AVERTED COST RISK (BASE)	NET VALUE (BASE)	AVERTED COST RISK (95TH PERCENTILE)	NET VALUE (95TH PERCENTILE)	CHANGE IN COST EFFECTIVE-NESS?
40	$620,000	$214,502	($405,498)	$608,504	($11,496)	No

When the 95th percentile PRA results are used, four of the Phase 2 SAMAs (8, 32, 36 and 37) that were previously classified as not cost effective are now determined to be cost effective. The use of the 95th percentile PRA results is not considered to provide the most rational assessment of the cost effectiveness of a SAMA; however, these additional SAMAs should be considered for implementation to address the uncertainties inherent in the SAMA analysis.

E.7.3 MACCS2 INPUT VARIATIONS

The MACCS2 model was developed using the best information available for the HCGS site; however, reasonable changes to modeling assumptions can lead to variations in the Level 3 results. In order to determine how certain assumptions could impact the SAMA results, a sensitivity analysis was performed on parameters that have previously been shown to impact the Level 3 results. These parameters include:

- Meteorological data
- Evacuation timing and speed
- Release height and heat
- Population estimates
- Population resettlement planning
- Economic rate of return

The risk metrics produced by MACCS2 that are evaluated in the sensitivity analyses are the 50 mile population dose and the 50 mile offsite economic cost. The subsections below discuss the changes in these results for each of the sensitivity parameters noted above. The final subsection, E.7.3.7, correlates the worst case changes identified in the sensitivity runs to a change in the site's averted cost-risk and discusses the implications of the sensitivity analysis on the SAMA analysis.

SENSITIVITY OF HCGS BASELINE RISK TO PARAMETER CHANGES

PARAMETER	DESCRIPTION	POP. DOSE RISK Δ BASE (%)	COST RISK Δ BASE (%)
Meteorology	Year 2005 Meteorology	-1%	-2%
	Year 2006 Meteorology	-2%	-1%
	Year 2007 Meteorology	-3%	-7%
Evacuation Time	Evacuation delay time increased from 65 minutes to 130 minutes (factor of 2)	+1%	0%
Evacuation Speed	Average evacuation speed decreased 50% from 2.8 m/sec to 1.4 m/sec.	+2%	0%
Release Height	Release height set to ground level (in lieu of top of containment).	-6%	-7%
Release Heat	Buoyant plume assumed (10 MW for each plume segment, except for intact containment release).	-1%	-1%
Population	Year 2046 population uniformly increased 30%	+29%	+30%
Resettlement Planning	No "Intermediate Phase" resettlement planning (in lieu of 6 months)	+14%	-37%
	1 year "Intermediate Phase" resettlement planning (in lieu of 6 months)	-11%	+39%
Rate of Return	3% expected rate of return (in lieu of 7%)	+2%	-9%
	12% expected rate of return (in lieu of 7%)	-1%	+10%

E.7.3.1 METEOROLOGICAL SENSITIVITIES

In addition to the year 2004 base case meteorological data, years 2005, 2006, and 2007 were also analyzed. Analysis of year 2005, 2006, and 2007 data sets yielded population dose-risks and cost risks that were 1% to 7% less than 2004 results. As no particular criteria have been defined by the industry related to determining which meteorological data set should be used as a base case for a site, the year 2004 data is chosen for HCGS given that it represents the most complete data set and results in higher results than the other data sets.

E.7.3.2 EVACUATION SENSITIVITIES

The sensitivity of two evacuation parameters was assessed. The delay time to evacuation (increased from 65 minutes to 130 minutes) was found to have a very minor impact (approximately 1% increase) on population dose risk. The evacuation speed sensitivity which decreased the average radial evacuation speed by a factor of two (from 2.8 m/sec to 1.4 m/sec) demonstrates a similar impact. The population dose risk increased approximately 2% using the slower evacuation speed. An increase in population dose is the expected result for a slower evacuation speed since evacuees would be expected to be exposed to releases for a longer period of time. It is noted that while evacuation assumptions do impact the population dose-risk estimates, they do not impact MACCS2 offsite economic cost-risk estimates because MACCS2 calculated cost-risks are based on land contamination levels which remain unaffected by evacuation assumptions and the number of people evacuating.

E.7.3.3 RELEASE HEIGHT & HEAT SENSITIVITIES

The release height sensitivity case quantifies the impact of the assumption related to the height of the release of the plumes. The baseline case assumes that the releases occur at the top of reactor building (61m) which tends to disperse material over a wider geographical region, generally impacting more people and creating larger cleanup costs. A ground level release height shows a decrease in dose risk and cost risk of 6% and 7%, respectively.

The release heat sensitivity case evaluates the impact of neglecting thermal plume effects. The base case assumed no thermal plume heat in the releases (e.g., no buoyant plumes). The sensitivity case assumed a heat content of 10 MW per plume segment, except for the intact containment release category. Increasing the plume heat contents resulted in differing results for individual releases (i.e., results of some release categories increased while others decreased.) The net result is a very minor dose-risk and cost risk decrease of 1% when 10 MW plume heat content values are applied.

E.7.3.4 POPULATION SENSITIVITY

A population sensitivity case assesses the impact of population assumptions. The base case year 2046 population is uniformly increased by 30% in all sectors of the 50-mile radius. This change has a significant impact on the dose risk and cost risk, increasing dose risk and cost risk by 29% and 30%, respectively. This sensitivity case demonstrates a significant dependence upon population estimates. This dependence is expected given that population dose and offsite economic costs are primarily driven by the regional population.

E.7.3.5 RESETTLEMENT PLANNING SENSITIVITIES

The MACCS2 consequence modeling incorporates an “intermediate phase” which depicts the time period following the release and immediate evacuation actions (termed the “early phase”) and extends to the time when recovery efforts such as decontamination and resettlement of people are begun (termed the “long term phase”). The intermediate phase thus models the time period when decontamination and resettlement plans are being developed. MACCS2 allows the habitation of land during the intermediate phase unless projected dose criteria is exceeded, in which case individuals are relocated. MACCS2 allows an intermediate phase ranging from no intermediate phase to one year. The intermediate phase sensitivities show significant impacts and are therefore discussed further:

- The no intermediate phase resettlement planning case is developed based on the NUREG-1150 modeling approach. The 37% reduction in cost risk seen in the sensitivity results, however, are judged too optimistic in that the land decontamination efforts are modeled as starting one week after the accident (i.e., directly after the early phase ends) such that a significant portion of population relocation costs are omitted. For instance, the costs associated with temporary housing of interdicted individuals while decontamination strategies are developed and decontamination teams are contracted are not accounted for without an intermediate phase. A competing factor is that the population dose increases (14% increase over the base case) because people are allowed to re-occupy the land sooner. It is believed that the NUREG-1150 studies omitted the intermediate phase because the intermediate phase coding was not validated at that time (NRC 1998a).
- The 1 year intermediate phase resettlement planning case is developed based on the maximum length of time allowed by MACCS2 for the intermediate phase. A long intermediate phase can be unrealistic in that re-occupation of contaminated land is

not performed during this phase even if contamination levels decrease (by natural radioactive decay) to levels which would allow it (i.e., resettlement is evaluated as part of the long term phase, not the intermediate phase). Therefore population relocation costs may be over estimated using a long (i.e., one year) intermediate phase. An intermediate phase of one year shows a 39% increase in cost risk estimates compared with the base case selection of 6 months. The population dose decreased by 11% with a longer intermediate phase due to later resettlement on decontaminated land.

- The six month intermediate phase (base case) is judged to be a best estimate approach in that it provides reasonable time for both decontamination and resettlement planning to be performed. The sensitivity cases demonstrate that the six month value used in the base case provides mid-range results for the modeling choices available.

E.7.3.6 RATE OF RETURN SENSITIVITIES

One of the economic cost components included in the MACCS2 calculated cost result is the financial loss associated with property and associated improvements (e.g., buildings) not achieving their expected annual rate of return during interdiction periods. A piece of land that is interdicted (i.e., not occupied) for a period of years will not achieve the historical rate of return or the rate of return achieved by other non-impacted properties during the interdiction period. This lack of expected return is an economic loss for the owner / society. The base case assumes a 7% expected rate of return, consistent with NRC guidance (NRC 2004). A sensitivity case using a 3% expected rate of return (NRC 2004) shows a decrease in the expected cost risk of approximately 9%. This decrease in cost risk associated with the lower rate or return is expected since there is a lower expectation associated with the land's return on investment. A sensitivity case using a 12% expected rate of return, the value used in NUREG-1150 MACCS2 analyses (NRC 1990b), shows an increase cost risk of approximately 10%. For both sensitivity cases the dose risk changes are minor (1% to 2%).

E.7.3.7 IMPACT ON SAMA ANALYSIS

Several different Level 3 input parameters are examined as part of the HCGS MACCS2 sensitivity analysis. The primary reason for performing these sensitivity runs is to identify any reasonable changes that could be made to the Level 3 input parameters that would impact the conclusions of the SAMA analysis. While the table in Section E.7.3 summarizes the changes to the dose-risk and OECR estimates for each sensitivity case, it is prudent to consider if any of these changes would result in the retention of the SAMAs that were screened using the baseline results.

Of all the MACCS2 sensitivity cases, the largest dose-risk increase, 29%, occurred in the Population (Year 2046 population uniformly increased 30%) case. The largest OECR increase, 39%, occurred in the Resettlement Planning (1 year "Intermediate Phase" resettlement planning in lieu of 6 months). Subsequently, the HCGS MMACR was recalculated using these results to determine the impact of using the worst case for each parameter simultaneously. The resulting MMACR is a factor of 1.35 greater than the base case, which is significantly less than the average factor of 2.84 calculated in Section E.7.2 for the 95th percentile individual SAMA PRA model results. Therefore, the 95th percentile PRA results sensitivity is considered to bound this case and no SAMAs would be retained based on this sensitivity that were not already identified in Section E.7.2.

E.8 CONCLUSIONS

The benefits of revising the operational strategies in place at HCGS and/or implementing hardware modifications can be evaluated without the insight from a risk-based analysis. However, use of the PRA in conjunction with cost-benefit analysis methodologies provides an enhanced understanding of the effects of the proposed changes relative to the cost of implementation and projected impact on a larger future population. The results of this study indicate that several potential improvements were identified that warrant further review for potential implementation at HCGS.

In summary, based on the given implementation costs, a number of SAMAs have been identified as cost-beneficial at the 95th percentile and are suggested for potential implementation at HCGS. While these results are believed to accurately reflect potential areas for improvement at the plant, PSEG notes that this analysis should not necessarily be considered a formal disposition of these proposed changes as other engineering reviews are necessary to determine the ultimate resolution. For the identified cost-beneficial SAMAs listed below, PSEG will disposition them using the existing Plant Health Committee processes.

SAMA 1: Remove ADS Inhibit from Non-ATWS Emergency Operating Procedures

SAMA 3: Install Back-Up Air Compressor to Supply AOVs

SAMA 4: Provide Procedural Guidance to Cross-Tie RHR Trains

SAMA 8: Convert Selected Fire Protection Piping from Wet to Dry Pipe System

SAMA 10: Provide Procedural Guidance to Use B.5.b Low Pressure Pump for Non-Security Events

SAMA 17: Replace a Supply Fan with a Different Design in Service Water Pump Room

SAMA 18: Replace a Return Fan with a Different Design in Service Water Pump Room

SAMA 30: Provide Procedural Guidance for Partial Transfer of Control Functions from the Control Room to the Remote Shutdown Panel

SAMA 32: Install Additional Physical Barriers to Limit Dispersion of Fuel Oil from DG Rooms

SAMA 35: Relocate, Minimize, and/or Eliminate Electrical Heaters in Electrical Access Room

SAMA 36: Provide Procedural Guidance for Loss of All 1E 120V AC Power

SAMA 37: Reinforce 1E 120V AC Distribution Panels

SAMA 39: Provide Procedural Guidance to Bypass RCIC Turbine Exhaust Pressure Trip

E.9 TABLES

TABLE E.2-1
HOPE CREEK PRA MODEL SUMMARY

MODEL REVISION DATE	MODEL NAME	INTERNAL EVENTS EXCLUDING INTERNAL FLOODING (1/YR)	INTERNAL FLOODING (1/YR)	TOTAL CDF (1/YR)	TOTAL LERF (1/YR)	TRUNC. LIMIT (1/YR)	REFERENCE (SECTION E.11)	NOTES
May 1994	IPE	4.59E-05	5.50E-07	4.65E-05	9.42E-6	1E-10	PSEG 1994a	1
Sep. 1994	Model 0	1.29E-05	5.50E-07	1.34E-05	9.42E-6	1E-10	PSEG 1994b	2
July 1999	Model 1.0	1.80E-05	5.50E-07	1.85E-05	8.95E-07	1E-10	PSEG 1999	3
March 2000	Model 1.1	1.05E-05	5.50E-07	1.11E-05	NR	1E-10	PSEG 2000a	4
June 2000	Model 1.2	8.70E-06	5.50E-07	9.25E-05	1.00E-06	1E-10	PSEG 2000b	5
Oct. 2000	Model 1.3	8.66E-06	5.50E-07	9.25E-05	1.00E-06	1E-10	PSEG 2000c	6
Aug. 2003	Model 2003A	3.13E-05	1.17E-07	3.14E-05	1.05E-6	5E-11	PSEG 2003	7
Oct. 2004	Rev. 2.0	1.66E-05	8.13E-08	1.67E-05	NR	1E-10	PSEG 2004	8
Oct. 2005	Model 2005A	--	--	--	--	--	PSEG 2006a	9
Nov. 2005	Model 2005B	1.00E-5	7.45E-08	1.01E-05	--	5E-11	PSEG 2006a	10
Feb. 2006	Model 2005C	9.69E-6	7.45E-08	9.76E-06	2.59E-07	5E-11	PSEG 2006a	11
Aug. 2008	HC108A	--	--	7.60E-06	8.63E-07	5E-11	PSEG 2008a	12
Dec. 2008	HC108B	4.99E-06	1.19E-07	5.11E-06	4.76E-07	1E-12	PSEG 2008b	13

Notes:

1. Note that the internal flooding analysis is retained from the IPE.
2. Note that the internal flooding analysis is retained from the IPE.
3. Note that the internal flooding analysis is retained from the IPE.
4. Note that the internal flooding analysis is retained from the IPE.
5. Note that the internal flooding analysis is retained from the IPE.
6. Note that the internal flooding analysis is retained from the IPE. It is also important to note that even though the LERF value was the same as the previous model, it was recalculated in Model 1.3.
7. The main change in this model is the conversion from NUPRA to CAFTA. The 2003A model is the result of a regularly scheduled update.
8. This model includes PSEG modifications on 480 VAC dependencies, SACS, success criteria, and SACS-SW HEPs.
9. This PRA model revision addresses conservatism in the Rev. 2.0 model. The above table does not include values for this Model revision. This revision is addressed in the above table to provide a complete history of the Hope Creek PRA. See 2005B for values.
10. This PRA model was used as input for the EPU submittal. It removes conservatism introduced in the Rev. 2.0 model (e.g. SACS heat load manipulation HEPs). The 2005B and C models included a modified SACS/SSW success criteria based on detailed PSEG calculations, which accounted for the removal of excess conservatism in the 2003A PRA model.

11. This revision modifies the 2005B EPU model to support online maintenance evaluations and MSPI calculations. The only PRA model change from the 2005B EPU PRA model to the 2005C Base PRA model is to reduce the turbine trip initiating event frequency from 1.25/yr to 1.03/yr to reflect plant specific operating history. The 2005B and C models included a modified SACS/SSW success criteria based on detailed PSEG calculations. This accounted for the removal of excess conservatism in the 2003A PRA model.
12. The HC108A model has been peer-reviewed against the ASME PRA Standard (see Section E.2.3)
13. Note that the current HC108B CAFTA model truncation limit has decreased compared to the previous HC108A model. This lower truncation limit was used with the FTREX quantification engine, which allowed more efficient quantification at a lower truncation limit (1E-12/yr) in order to meet MSPI convergence criteria.

TABLE E.2-2
HOPE CREEK 2008 PRA LEVEL 2 LERF CONTRIBUTION BY INITIATING EVENT (HC108B)

BASIC EVENT ID	DESCRIPTION	FREQUENCY (/YR)	F-V	LERF (/YR)	CLERP
%IE-ISLOCAD	ISLOCA INITIATOR FOR ECCS DISCHARGE PATHS	1.63E-05	2.34E-01	1.11E-07	6.83E-03
%IE-TT	TURBINE TRIP WITH BYPASS	7.03E-01	1.54E-01	7.32E-08	1.04E-07
%IE-TE	LOSS OF OFFSITE POWER INITIATING EVENT	2.37E-02	1.37E-01	6.52E-08	2.75E-06
%IE-SWS	LOSS OF SERVICE WATER INITIATING EVENT	1.79E-04	6.74E-02	3.21E-08	1.79E-04
%IE-S2-ST	SMALL LOCA - STEAM (ABOVE TAF)	6.20E-04	6.40E-02	3.04E-08	4.91E-05
%IE-S2-WA	SMALL LOCA - WATER (BELOW TAF)	6.20E-04	6.10E-02	2.90E-08	4.68E-05
%FLTORUS	TORUS RUPTURE IN TORUS ROOM	2.80E-06	3.24E-02	1.54E-08	5.50E-03
%IE-MS	MANUAL SHUTDOWN INITIATING EVENT	1.46E+00	2.77E-02	1.32E-08	9.02E-09
%IE-TC	LOSS OF CONDENSER VACUUM	9.33E-02	2.69E-02	1.28E-08	1.37E-07
%IE-SORV2	2 or More SORVs	2.44E-04	2.09E-02	9.94E-09	4.07E-05
%FLFPS-CR	FPS RUPTURE OUTSIDE CONTROL ROOM	1.10E-05	1.76E-02	8.37E-09	7.61E-04
%IE-TM	MSIV CLOSURE	5.62E-02	1.56E-02	7.42E-09	1.32E-07
%FLTORUSRB	TORUS SUCTION LINE RUPTURE IN ECCS ROOM	2.70E-06	1.25E-02	5.95E-09	2.20E-03
%IE-TF	LOSS OF FEEDWATER	4.49E-02	1.23E-02	5.85E-09	1.30E-07
%FL-FPS-5302	INT. FLOOD OUTSIDE LOWER RELAY ROOM	6.62E-06	9.50E-03	4.52E-09	6.83E-04
%IE-ISLOCAS	ISLOCA INITIATOR FOR SDC SUCTION PATH	5.01E-07	8.15E-03	3.88E-09	7.74E-03
%FLSWAB-RACS-U	FREQ OF COMMON HEADER TO RACS RUPTURE (UNISOLABLE)	7.60E-08	7.83E-03	3.72E-09	4.90E-02
%FLSWA-RACS-U	FREQ. OF UNISOLABLE SW A PIPE RUPT IN RACS ROOM	5.70E-08	5.87E-03	2.79E-09	4.90E-02
%FLSWB-RACS-U	FREQ. OF UNISOLABLE SW B PIPE RUPT. IN RACS ROOM	5.70E-08	5.87E-03	2.79E-09	4.90E-02
%IE-BOCMSA	Main Steam Line A Break outside Containment	9.66E-09	5.29E-03	2.52E-09	2.60E-01
%IE-BOCMSB	Main Steam Line B Break outside	9.66E-09	5.29E-03	2.52E-09	2.60E-01

TABLE E.2-2
HOPE CREEK 2008 PRA LEVEL 2 LERF CONTRIBUTION BY INITIATING EVENT (HC108B)

BASIC EVENT ID	DESCRIPTION	FREQUENCY (/YR)	F-V	LERF (/YR)	CLERP
%IE-BOCMSC	Main Steam Line C Break outside	9.66E-09	5.29E-03	2.52E-09	2.60E-01
%IE-BOCMSD	Main Steam Line D Break outside	9.66E-09	5.29E-03	2.52E-09	2.60E-01
%IE-SACS	LOSS OF SACS INITIATING EVENT	1.16E-04	4.02E-03	1.91E-09	1.65E-05
%IE-TI	INADVERTENTLY OPEN SRV INITIATING EVENT	1.44E-02	3.77E-03	1.79E-09	1.25E-07
%IE-LLRHR	Large LOCA – RHR	9.69E-06	2.92E-03	1.39E-09	1.43E-04
%IE-LLMS	Large LOCA – Main Steam	1.00E-05	2.91E-03	1.38E-09	1.38E-04
%IE-BOCHPCI	HPCI Steam Line Break outside Containment	5.11E-09	2.80E-03	1.33E-09	2.61E-01
%IE-BOCRCIC	RCIC Steam Line Break outside Containment	5.11E-09	2.80E-03	1.33E-09	2.61E-01
%IE-BOCRWCU	RWCU Line Break outside Containment	5.11E-09	2.80E-03	1.33E-09	2.61E-01
%IE-LLRECIRC	Large LOCA – Reactor Recirculation	8.74E-06	2.64E-03	1.26E-09	1.44E-04
%IE-LLADS	Large LOCA - Spurious ADS Actuation	8.48E-06	2.46E-03	1.17E-09	1.38E-04
%IE-MLRHR	Medium LOCA – RHR	1.44E-05	2.32E-03	1.10E-09	7.66E-05
%IE-IAS	LOSS OF INSTRUMENT AIR INITIATOR	6.17E-03	2.17E-03	1.03E-09	1.67E-07
%IE-MLRECIRC	Medium LOCA – Reactor Recirculation	1.18E-05	1.90E-03	9.04E-10	7.66E-05
%FLFPS-RBU	FPS RUPTURE IN RB UPPER LEVELS	6.60E-05	1.81E-03	8.61E-10	1.30E-05
%FLSWA-RACS-I	FREQ. OF ISOLABLE SW A PIPE RUPTURE IN RACS ROOM	1.43E-06	1.77E-03	8.42E-10	5.89E-04
%FLSWB-RACS-I	FREQ. OF ISOLABLE SW B PIPE RUPTURE IN RACS ROOM	1.43E-06	1.77E-03	8.42E-10	5.89E-04
%IE-TE-REC	LOSS OF OFFSITE POWER INITIATING EVENT (RECOVERED LOOP EVENT)	2.37E-02	1.58E-03	7.51E-10	3.17E-08
%IE-LLCS	Large LOCA - Core Spray	5.40E-06	1.56E-03	7.42E-10	1.37E-04
%IE-MLRWCU	Medium LOCA – RWCU	8.63E-06	1.37E-03	6.52E-10	7.55E-05
%IE-LLFW	Large LOCA – Feedwater	4.53E-06	1.35E-03	6.42E-10	1.42E-04

TABLE E.2-2
HOPE CREEK 2008 PRA LEVEL 2 LERF CONTRIBUTION BY INITIATING EVENT (HC108B)

BASIC EVENT ID	DESCRIPTION	FREQUENCY (/YR)	F-V	LERF (/YR)	CLERP
%IE-LLRWCU	Large LOCA – RWCU	4.53E-06	1.35E-03	6.42E-10	1.42E-04
%FLFPS-5537	FPS RUPTURE OUTSIDE 125V DC ROOMS	1.34E-05	1.34E-03	6.37E-10	4.76E-05
%IE-ACD	LOSS OF AC BUS D INITIATING EVENT	2.07E-03	1.25E-03	5.95E-10	2.87E-07
%IE-BOCFWA	Feedwater Line A Break outside	2.23E-09	1.22E-03	5.80E-10	2.60E-01
%IE-BOCFWB	FEEDWATER LINE B BREAK OUTSIDE CONTAINMENT	2.23E-09	1.22E-03	5.80E-10	2.60E-01
%IE-MLMS	Medium LOCA – Main Steam	1.54E-05	1.21E-03	5.75E-10	3.74E-05
%IE-MLFW	Medium LOCA – Feedwater	7.22E-06	1.14E-03	5.42E-10	7.51E-05
%IE-MLNBINST	Medium LOCA – Nuclear Boiler Instrumentation	5.24E-06	8.11E-04	3.86E-10	7.36E-05
%IE-MLCS	Medium LOCA – Core Spray	9.34E-06	7.29E-04	3.47E-10	3.71E-05
%FLSACS-A	SACS A RUPTURE	2.70E-04	6.06E-04	2.88E-10	1.07E-06
%FLSW-SACS-B	SW RUPTURE IN SACS B ROOM	4.80E-07	3.54E-04	1.68E-10	3.51E-04
%IE-MLHPCI	Medium LOCA – HPCI	1.80E-06	3.28E-04	1.56E-10	8.67E-05
%FLTB-CW	TURBINE BUILDING FLOOD	1.50E-03	3.23E-04	1.54E-10	1.02E-07
%IE-LLHPCI	Large LOCA – HPCI	1.13E-06	3.21E-04	1.53E-10	1.35E-04
%IE-ACA	LOSS OF AC BUS A INITIATING EVENT	2.89E-04	2.89E-04	1.37E-10	4.76E-07
%IE-ACB	LOSS OF AC BUS B INITIATING EVENT	2.89E-04	2.82E-04	1.34E-10	4.64E-07
%IE-MLRCIC	Medium LOCA – RCIC	3.27E-06	2.38E-04	1.13E-10	3.46E-05
%FLSW-SACS-A	SW RUPTURE IN SACS A ROOM	4.80E-07	2.23E-04	1.06E-10	2.21E-04
%IE-R	EXCESSIVE LOCA EVENT	6.38E-09	1.79E-04	8.51E-11	1.33E-02
%FLSACS-B	SACS B RUPTURE	2.70E-04	1.75E-04	8.32E-11	3.08E-07
%IE-DCAB	LOSS OF DCA & DCB	7.14E-07	9.01E-05	4.29E-11	6.00E-05
%FLFPS-CD	FPS RUPTURE IN CONTROL DIESEL BUILDING	8.20E-05	7.21E-05	3.43E-11	4.18E-07

TABLE E.2-2
HOPE CREEK 2008 PRA LEVEL 2 LERF CONTRIBUTION BY INITIATING EVENT (HC108B)

BASIC EVENT ID	DESCRIPTION	FREQUENCY (/YR)	F-V	LERF (/YR)	CLERP
%IE-ACC	LOSS OF AC BUS C INITIATING EVENT	2.89E-04	2.92E-05	1.39E-11	4.81E-08
%FLSWAB-RACS-I	FREQ. OF ISOLABLE SW A & B PIPE RUPTURE IN RACS ROOM (TO RACS HX)	5.70E-07	2.42E-05	1.15E-11	2.02E-05

TABLE E.2-3
RELEASE SEVERITY AND TIMING CLASSIFICATION SCHEME(1)

RELEASE SEVERITY		RELEASE TIMING	
CLASSIFICATION CATEGORY	**CS IODIDE % IN RELEASE**	**CLASSIFICATION CATEGORY**	**TIME OF INITIAL RELEASE(2) 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)	4 to 24 hours
Low (L)	0.1 to 1	Early (E)	Less than 4 hours
Low-low (LL)	Less than 0.1		
No iodine (OK)	0		

(1) The combinations of severity and timing classifications results in one OK release category and 12 other release categories of varying times and magnitudes.

(2) The cue for the General Emergency declaration is taken to be the time when EALs are exceeded. The declaration of the General Emergency begins the time for evacuation.

TABLE E.2-4
SUMMARY OF CONTAINMENT EVALUATION

INPUT		OUTPUT	
LEVEL 1 PRA		CET EVALUATION	
CORE DAMAGE FREQUENCY	CHARACTERIZE RELEASE	RELEASE BIN(1)	RELEASE FREQUENCY (PER YEAR)(4)
	Little or No Release	OK	2.12E-06
	Low Public Risk Impact	LL and Late	3.90E-08
		LL and I	2.87E-07
		LL and E	9.30E-08
		L and Late(2)	2.88E-07
		L and I	7.71E-09
		L and E	5.95E-10
	Moderate Public Risk Impact	M and Late (2)	0.00E+00
		M and I	3.17E-07
		M and E	3.57E-07
	High Release	H and Late(2)	1.26E-07
		H and I	1.15E-06
		H and E	4.72E-07(3)

(1) See Table E.2-3 for nomenclature on the release bins.

(2) One of the areas that PRA tools are somewhat limited is in the estimation of recovery or repair during extended times such as 24 hours. Some estimates would indicate that response over such an extended time could be very extensive and highly successful. Therefore, it can be argued that virtually no accidents that take beyond 24 hours to release should be considered to be a significant potential contributor to public risk.

(3) The accident class LERF total of 4.72E-7/yr is slightly lower than the base Level 2 LERF total of 4.76E-7/yr from the single top model. This may be due to the assumption that all Class IV end states were decreased proportionally due to the success branch probability issue. The Level 2 LERF total of 4.76E-7/yr from the single top model is judged to be the appropriate LERF result.

(4) Release frequencies were calculated at a truncation limit of 1E-12/yr.

TABLE E.2-5
HCGS HC108B LEVEL 1 CDF CONTRIBUTION BY INITIATING EVENT
(CDF = 5.11E-6/YR AT 1E-12/YR TRUNCATION)

BASIC EVENT ID	DESCRIPTION	Frequency (/yr)	F-V	CDF (/yr)	CCDP
%IE-TE	LOSS OF OFFSITE POWER INITIATING EVENT	2.37E-02	1.82E-01	9.31E-07	3.93E-05
%IE-SWS	LOSS OF SERVICE WATER INITIATING EVENT	1.79E-04	1.59E-01	8.13E-07	4.54E-03
%IE-MS	MANUAL SHUTDOWN INITIATING EVENT	1.46E+00	1.50E-01	7.67E-07	5.25E-07
%IE-TT	TURBINE TRIP WITH BYPASS	7.03E-01	1.22E-01	6.24E-07	8.87E-07
%IE-S2-WA	SMALL LOCA - WATER (BELOW TAF)	6.20E-04	5.40E-02	2.76E-07	4.45E-04
%IE-S2-ST	SMALL LOCA - STEAM (ABOVE TAF)	6.20E-04	4.45E-02	2.28E-07	3.67E-04
%IE-TC	LOSS OF CONDENSER VACUUM	9.33E-02	3.98E-02	2.03E-07	2.18E-06
%FLFPS-CR	FPS RUPTURE OUTSIDE CONTROL ROOM	1.10E-05	3.62E-02	1.85E-07	1.68E-02
%IE-ISLOCAD	ISLOCA INITIATOR FOR ECCS DISCHARGE PATHS	1.63E-05	2.22E-02	1.14E-07	6.96E-03
%IE-TM	MSIV CLOSURE	5.62E-02	2.16E-02	1.10E-07	1.97E-06
%FL-FPS-5302	INT. FLOOD OUTSIDE LOWER RELAY ROOM	6.62E-06	1.90E-02	9.71E-08	1.47E-02
%IE-TF	LOSS OF FEEDWATER	4.49E-02	1.72E-02	8.79E-08	1.96E-06
%IE-SACS	LOSS OF SACS INITIATING EVENT	1.16E-04	1.54E-02	7.87E-08	6.79E-04
%FLSWAB-RACS-U	FREQ OF COMMON HEADER TO RACS RUPTURE (UNISOLABLE)	7.60E-08	1.49E-02	7.62E-08	1.00E+00
%FLSWA-RACS-U	FREQ. OF UNISOLABLE SW A PIPE RUPT IN RACS ROOM	5.70E-08	1.11E-02	5.68E-08	9.96E-01
%FLSWB-RACS-U	FREQ. OF UNISOLABLE SW B PIPE RUPT. IN RACS ROOM	5.70E-08	1.11E-02	5.68E-08	9.96E-01
%IE-ACD	LOSS OF AC BUS D INITIATING EVENT	2.07E-03	7.78E-03	3.98E-08	1.92E-05
%IE-SORV2	2 or More SORVs	2.44E-04	6.19E-03	3.16E-08	1.30E-04
%FLFPS-RBU	FPS RUPTURE IN RB UPPER LEVELS	6.60E-05	5.60E-03	2.86E-08	4.34E-04
%FLSWA-RACS-I	FREQ. OF ISOLABLE SW A PIPE RUPTURE IN RACS ROOM	1.43E-06	5.14E-03	2.63E-08	1.84E-02
%FLSWB-RACS-I	FRQ. OF ISOLABLE SW B PIPE RUPTURE IN RACS ROOM	1.43E-06	4.87E-03	2.49E-08	1.74E-02
%IE-TI	INADVERTENTLY OPEN SRV INITIATING EVENT	1.44E-02	4.82E-03	2.46E-08	1.71E-06
%IE-IAS	LOSS OF INSTRUMENT AIR INITIATOR	6.17E-03	4.50E-03	2.30E-08	3.73E-06
%IE-MLRHR	Medium LOCA – RHR	1.44E-05	4.08E-03	2.09E-08	1.45E-03
%IE-MLRECIRC	Medium LOCA – Reactor Recirculation	1.18E-05	3.34E-03	1.71E-08	1.45E-03
%FLTORUS	TORUS RUPTURE IN TORUS ROOM	2.80E-06	3.32E-03	1.70E-08	6.06E-03
%IE-ACA	LOSS OF AC BUS A INITIATING EVENT	2.89E-04	2.96E-03	1.51E-08	5.24E-05
%FL-FPS-5537	FPS RUPTURE OUTSIDE 125V DC ROOMS	1.34E-05	2.62E-03	1.34E-08	1.00E-03

TABLE E.2-5
HCGS HC108B LEVEL 1 CDF CONTRIBUTION BY INITIATING EVENT
(CDF = 5.11E-6/YR AT 1E-12/YR TRUNCATION)

BASIC EVENT ID	DESCRIPTION	Frequency (/yr)	F-V	CDF (/yr)	CCDP
%IE-MLRWCU	Medium LOCA – RWCU	8.63E-06	2.44E-03	1.25E-08	1.45E-03
%IE-TE-REC	LOSS OF OFFSITE POWER INITIATING EVENT (RECOVERED LOOP EVENT)	2.37E-02	2.28E-03	1.17E-08	4.92E-07
%IE-MLFW	Medium LOCA – Feedwater	7.22E-06	2.04E-03	1.04E-08	1.44E-03
%FLFPS-CD	FPS RUPTURE IN CONTROL DIESEL BUILDING	8.20E-05	1.79E-03	9.15E-09	1.12E-04
%IE-MLNBINST	Medium LOCA – Nuclear Boiler Instrumentation	5.24E-06	1.48E-03	7.57E-09	1.44E-03
%FLTORUSRB	TORUS SUCTION LINE RUPTURE IN ECCS ROOM	2.70E-06	1.28E-03	6.54E-09	2.42E-03
%IE-ACB	LOSS OF AC BUS B INITIATING EVENT	2.89E-04	1.22E-03	6.24E-09	2.16E-05
%FLSW-SACS-A	SW RUPTURE IN SACS A ROOM	4.80E-07	1.06E-03	5.42E-09	1.13E-02
%FLSACS-A	SACS A RUPTURE	2.70E-04	7.97E-04	4.07E-09	1.51E-05
%IE-ISLOCAS	ISLOCA INITIATOR FOR SDC SUCTION PATH	5.01E-07	7.58E-04	3.88E-09	7.74E-03
%FLSW-SACS-B	SW RUPTURE IN SACS B ROOM	4.80E-07	7.03E-04	3.59E-09	7.49E-03
%IE-LLRHR	Large LOCA – RHR	9.69E-06	6.26E-04	3.20E-09	3.30E-04
%IE-MLHPCI	Medium LOCA – HPCI	1.80E-06	5.92E-04	3.03E-09	1.68E-03
%FLSACS-B	SACS B RUPTURE	2.70E-04	5.66E-04	2.89E-09	1.07E-05
%IE-ACC	LOSS OF AC BUS C INITIATING EVENT	2.89E-04	5.60E-04	2.86E-09	9.91E-06
%IE-LLRECIRC	Large LOCA – Reactor Recirculation	8.74E-06	5.50E-04	2.81E-09	3.22E-04
%FLTB-CW	TURBINE BUILDING FLOOD	1.50E-03	5.27E-04	2.69E-09	1.80E-06
%IE-BOCMSA	Main Steam Line A Break outside Containment	9.66E-09	4.92E-04	2.52E-09	2.60E-01
%IE-BOCMSB	Main Steam Line B Break outside	9.66E-09	4.92E-04	2.52E-09	2.60E-01
%IE-BOCMSC	Main Steam Line C Break outside	9.66E-09	4.92E-04	2.52E-09	2.60E-01
%IE-BOCMSD	Main Steam Line D Break outside	9.66E-09	4.92E-04	2.52E-09	2.60E-01
%IE-MLMS	Medium LOCA – Main Steam	1.54E-05	3.78E-04	1.93E-09	1.25E-04
%FLSWAB-RACS-I	FREQ. OF ISOLABLE SW A & B PIPE RUTPURE IN RACS ROOM (TO RACS HX)	5.70E-07	3.37E-04	1.72E-09	3.02E-03
%IE-LLMS	Large LOCA – Main Steam	1.00E-05	3.36E-04	1.72E-09	1.72E-04
%IE-MLCS	Medium LOCA – Core Spray	9.34E-06	3.15E-04	1.61E-09	1.72E-04
%IE-LLFW	Large LOCA – Feedwater	4.53E-06	2.85E-04	1.46E-09	3.22E-04
%IE-LLRWCU	Large LOCA – RWCU	4.53E-06	2.85E-04	1.46E-09	3.22E-04

TABLE E.2-5
HCGS HC108B LEVEL 1 CDF CONTRIBUTION BY INITIATING EVENT
(CDF = 5.11E-6/YR AT 1E-12/YR TRUNCATION)

BASIC EVENT ID	DESCRIPTION	Frequency (/yr)	F-V	CDF (/yr)	CCDP
%IE-LLADS	Large LOCA - Spurious ADS Actuation	8.48E-06	2.84E-04	1.45E-09	1.71E-04
%IE-BOCHPCI	HPCI Steam Line Break outside Containment	5.11E-09	2.60E-04	1.33E-09	2.60E-01
%IE-BOCRCIC	RCIC Steam Line Break outside Containment	5.11E-09	2.60E-04	1.33E-09	2.60E-01
%IE-BOCRWCU	RWCU Line Break outside Containment	5.11E-09	2.60E-04	1.33E-09	2.60E-01
%IE-LLCS	Large LOCA - Core Spray	5.40E-06	2.30E-04	1.18E-09	2.18E-04
%IE-DCAB	LOSS OF DCA & DCB	7.14E-07	1.44E-04	7.36E-10	1.03E-03
%IE-R	EXCESSIVE LOCA EVENT	6.38E-09	1.39E-04	7.11E-10	1.11E-01
%IE-BOCFWA	Feedwater Line A Break outside	2.23E-09	1.14E-04	5.83E-10	2.61E-01
%IE-BOCFWB	FEEDWATER LINE B BREAK OUTSIDE CONTAINMENT	2.23E-09	1.14E-04	5.83E-10	2.61E-01
%IE-MLRCIC	Medium LOCA – RCIC	3.27E-06	7.67E-05	3.92E-10	1.20E-04
%IE-LLHPCI	Large LOCA – HPCI	1.13E-06	3.63E-05	1.86E-10	1.64E-04
%IE-RACS	LOSS OF RACS	1.56E-05	5.86E-07	3.00E-12	1.92E-07

TABLE E.3-1
ESTIMATED POPULATION DISTRIBUTION WITHIN A 10-MILE RADIUS OF HCGS, YEAR 2046

SECTOR	0-1 MILE (1.00) (1)	1-2 MILES (1.00) (1)	2-3 MILES (1.00) (1)	3-4 MILES (1.19) (1)	4-5 MILES (1.38) (1)	5-10 MILES (1.17) (1)	10-MILE TOTAL(2)
N	0	0	0	0	0	1830	1830
NNE	0	0	0	0	105	15854	15959
NE	0	0	0	0	176	4512	4688
ENE	0	0	0	187	571	3500	4258
E	0	0	0	0	220	1734	1954
ESE	0	0	0	0	0	1674	1674
SE	0	0	0	0	0	0	0
SSE	0	0	0	0	0	129	129
S	0	0	0	90	0	1193	1283
SSW	0	0	0	0	0	1299	1299
SW	0	0	0	27	0	4706	4733
WSW	0	0	15	0	904	5183	6102
W	0	0	0	23	566	17065	17654
WNW	0	0	0	304	2138	6172	8614
NW	0	0	75	0	940	5686	6701
NNW	0	0	145	160	158	44577	45040
Total(2)	0	0	235	790	5778	115114	121917

(1) Radial ten year population growth factor applied successively to year 2000 census data to develop year 2046 estimate. Radial growth factor is based upon radial population growth from 1990 to year 2000.

(2) Population projections developed in electronic spreadsheet calculation and totals may differ slightly due to rounding of individual values.

TABLE E.3-2
ESTIMATED POPULATION DISTRIBUTION WITHIN A 50-MILE RADIUS OF HCGS, YEAR 2046

SECTOR	0-10 MILES	10-20 MILES (1.16) (1)	20-30 MILES (1.09) (1)	30-40 MILES (1.01) (1)	40-50 MILES (1.04) (1)	50-MILE TOTAL(2)
N	1830	246483	205299	162261	203948	819820
NNE	15959	26708	169874	969326	1326997	2508865
NE	4688	16670	98321	418531	531046	1069256
ENE	4258	8618	47490	80249	45510	186125
E	1954	65843	108963	22328	51820	250908
ESE	1674	17688	22482	9994	28862	80700
SE	0	141	835	0	48631	49607
SSE	129	108	1845	1413	7822	11317
S	1283	27990	88978	27767	18930	164948
SSW	1299	32553	16178	9882	17231	77143
SW	4733	7140	7738	6343	12701	38655
WSW	6102	7138	5135	11206	36303	65885
W	17654	9607	5916	55881	212030	301089
WNW	8614	42406	36834	30575	28271	146698
NW	6701	193335	42694	28418	52573	323721
NNW	45040	238574	113728	76381	66009	539732
Total(2)	121917	941003	972310	1910554	2688683	6634468

(1) Radial ten year population growth factor applied successively to year 2000 census data to develop year 2046 estimate. Radial growth factor is based upon radial population growth from 1990 to year 2000.

(2) Population projections developed in electronic spreadsheet calculation and totals may differ slightly due to rounding of individual values.

TABLE E.3-3
HCGS MACCS2 END OF CYCLE CORE INVENTORY

ENTRY	NUCLIDE	ACTIVITY (BQ)	ENTRY	NUCLIDE	ACTIVITY (BQ)
1	Co-58	2.22E+16	31	Te-131m	4.01E+18
2	Co-60	2.65E+16	32	Te-132	5.52E+18
3	Kr-85	4.78E+16	33	I-131	3.87E+18
4	Kr-85m	1.07E+18	34	I-132	5.61E+18
5	Kr-87	2.06E+18	35	I-133	7.99E+18
6	Kr-88	2.90E+18	36	I-134	8.78E+18
7	Rb-86	9.20E+15	37	I-135	9.01E+18
8	Sr-89	3.90E+18	38	Xe-133	7.68E+18
9	Sr-90	3.83E+17	39	Xe-135	2.64E+18
10	Sr-91	7.68E+18	40	Cs-134	7.75E+17
11	Sr-92	5.23E+18	41	Cs-136	2.70E+17
12	Y-90	4.07E+17	42	Cs-137	9.80E+17
13	Y-91	4.99E+18	43	Ba-139	7.17E+18
14	Y-92	5.25E+18	44	Ba-140	6.93E+18
15	Y-93	6.03E+18	45	La-140	7.36E+18
16	Zr-95	7.03E+18	46	La-141	6.54E+18
17	Zr-97	2.13E+19	47	La-142	6.33E+18
18	Nb-95	7.06E+18	48	Ce-141	6.58E+18
19	Mo-99	7.39E+18	49	Ce-143	6.12E+18
20	Tc-99m	6.46E+18	50	Ce-144	1.08E+19
21	Ru-103	1.12E+19	51	Pr-143	5.91E+18
22	Ru-105	3.91E+18	52	Nd-147	2.62E+18
23	Ru-106	4.26E+18	53	Np-239	7.57E+19
24	Rh-105	3.67E+18	54	Pu-238	1.31E+16
25	Sb-127	4.06E+17	55	Pu-239	1.58E+15
26	Sb-129	1.23E+18	56	Pu-240	2.04E+15
27	Te-127	4.03E+17	57	Pu-241	5.93E+17
28	Te-127m	5.38E+16	58	Am-241	6.67E+14
29	Te-129	1.21E+18	59	Cm-242	1.58E+17
30	Te-129m	1.80E+17	60	Cm-244	7.59E+15

TABLE E.3-4
MACCS2 RELEASE CATEGORIES VS. HCGS RELEASE CATEGORIES

MACCS2 RELEASE CATEGORIES	HCGS RELEASE CATEGORIES
Xe/Kr	1 – noble gases
I	2 – CsI
Cs	6 & 2 – CsOH and CsI(3)
Te	3 & 11- TeO_2, Sb(2) & Te_2 (1)
Sr	4 – SrO
Ru	5 – MoO_2 (Mo is in Ru MACCS category)
La	8 – La_2O_3
Ce	9 – CeO_2 & UO_2 (1)
Ba	7 – BaO

(1) These release fractions are typically negligible compared to others in the group.
(2) The mass of Sb in the core is typically much less than the mass of Te.
(3) The mass of Cs contained in CsI is typically much less than the mass of Cs contained in CsOH.

TABLE E.3-5
REPRESENTATIVE MAAP LEVEL 2 CASE DESCRIPTIONS AND KEY EVENT TIMINGS

SOURCE TERM	RELEASE CATEGORY	MAAP CASE	REPRESENTATIVE CASE DESCRIPTION	CSI RF(1)	TCD (HRS)(2)	TVF (HRS)(3)	TCF (HRS)(4)	TEND (HRS)(5)
ST1	H/E-HP	HC070500 IA-L2-NSPR	Loss of makeup at high pressure. No containment sprays.	0.57	0.60	3.0	3.2	38
ST2	H/E-LP	HC070504 ID-L2-NSPR	Loss of makeup at low pressure. No containment sprays.	0.15	0.47	4.7	4.8	38
ST3	H/E-BOC	HC070524 V-L2-17	Main steam line break outside containment. No injection. Release to environment begins at core damage.	0.69	0.13	6.8	6.9	38
ST4	H/I	HC070509 IIT-L2-WWW	Loss of containment heat removal and subsequent wetwell failure. RCIC and core spray provide injection. SRVs reclose at 50 psid. No containment sprays.	0.30	29.1	38.6	29.8	72
ST5	H/L	HC070515 IIA-L2-WWW	Loss of containment heat removal and subsequent wetwell failure. CRD, RCIC, and core spray provide injection. SRVs reclose at 50 psid. No containment sprays.	0.36	35.4	46.4	34.4	84
ST6	M/E	HC070519 IVA-L2-ED-WWA	ATWS event with SLC failure and emergency depressurization. FW, HPCI, and LPCI provide injection until containment failure.	0.070	0.77	5.4	0.58	38

TABLE E.3-5
REPRESENTATIVE MAAP LEVEL 2 CASE DESCRIPTIONS AND KEY EVENT TIMINGS

SOURCE TERM	RELEASE CATEGORY	MAAP CASE	REPRESENTATIVE CASE DESCRIPTION	CSI RF(1)	TCD (HRS)(2)	TVF (HRS)(3)	TCF (HRS)(4)	TEND (HRS)(5)
ST7	M/I	HC070516 IIA-L2-DW	Loss of containment heat removal and subsequent drywell failure. CRD, RCIC, and core spray provide injection. SRVs reclose at 50 psid. No containment sprays.	0.057	35.4	46.5	34.4	84
ST8	M/L	HC070502 IA-L2-SPRY-A	Loss of makeup at high pressure. Containment sprays fail at containment failure.	0.040	0.58	3.0	21.8	38
ST9	L / E, LL / E, L / I LL / I	HC070503 IA-L2-SPRY-B	Loss of makeup at high pressure. Containment sprays operate past containment failure.	2.3E-6	0.58	3.0	21.8	38
ST10	L / L, LL / L	HC070505 ID-L2-SPRY	Loss of makeup at low pressure. Containment sprays fail at containment failure.	9.8E-5	0.47	4.8	32.2	38
ST11	Intact	HC070525A OK-L2-A	Loss of makeup at high pressure. Containment sprays and suppression pool cooling operate. Intact containment with technical specification leakage.	1.7E-6	0.58	3.1	NA	38

Notes:

(1) CsI RF – Cesium Iodide release fraction to the environment
(2) Tcd - Time of core damage (maximum core temperature >1800°F)
(3) Tvf - Time of vessel breach
(4) Tcf – Time of containment failure
(5) Tend – Time at end of run

TABLE E.3-6
HCGS SOURCE TERM SUMMARY

	RELEASE CATEGORY										
	H/E-HP	**H/E-LP**	**H/E-BOC**	**H / I**	**H / L**	**M / E**	**M / I**	**M / L**	**L/E LL/E L/I LL/I**	**L/L LL/L**	**INTACT**
Bin Frequency	1.83E-07	7.15E-08	1.30E-07	9.70E-07	8.34E-08	3.48E-07	2.16E-07	0.00E+00	2.68E-07	2.39E-07	1.93E-06
MAAP Case	HC070500	HC070504	HC070524	HC070509	HC070515	HC070519	HC070516	HC070502	HC070503	HC070505	HC070525A
Run Duration	38 hr	38 hr	38 hr	72 hr	84 hr	38 hr	84 hr	38 hr	38 hr	38 hr	38 hr
Time after Scram when GE is declared (1)	30 min.	30 min.	30 min.	20 hr	20 hr	50 min.	20 hr	30 min.	30 min.	30 min.	30 min.
Fission Product Group:											
1) Noble											
Total Release Fraction	8.70E-01	7.70E-01	9.80E-01	9.90E-01	9.90E-01	9.90E-01	9.10E-01	5.00E-01	8.90E-01	9.80E-01	1.20E-02
Total Plume 1 Release Fraction	8.10E-01	6.50E-01	9.65E-01	8.40E-01	9.30E-01	9.50E-01	8.00E-01	4.70E-01	0.00E+00	0.00E+00	1.00E-03
Start of Plume 1 Release (hr)	3.10	4.75	0.17	30.00	36.00	1.00	35.00	22.00			3.00
End of Plume 1 Release (hr)	4.00	6.00	1.50	32.00	40.00	2.50	45.00	25.00			4.50
Total Plume 2 Release Fraction	3.00E-02	4.00E-02	5.00E-03	1.40E-01	4.00E-02	3.00E-02	2.00E-02	0.00E+00	0.00E+00	9.80E-01	1.00E-03
Start of Plume 2 Release (hr)	4.00	6.00	1.50	32.00	46.00	2.50	45.00			32.00	4.50
End of Plume 2 Release (hr)	6.00	14.00	4.00	34.00	50.00	7.00	50.00			38.00	8.00
Total Plume 3 Release Fraction	3.00E-02	8.00E-02	1.00E-02	1.00E-02	2.00E-02	1.00E-02	9.00E-02	3.00E-02	8.90E-01	0.00E+00	1.00E-02
Start of Plume 3 Release (hr)	6.00	14.00	6.90	38.00	50.00	7.00	50.00	32.00	22.00		8.00
End of Plume 3 Release (hr)	16.00	24.00	7.90	45.00	60.00	17.00	60.00	38.00	32.00		18.00
2) CsI											
Total Release Fraction	5.70E-01	1.50E-01	7.00E-01	3.00E-01	3.60E-01	7.00E-02	5.70E-02	4.00E-02	2.30E-06	9.80E-05	1.70E-06
Total Plume 1 Release Fraction	2.50E-01	2.00E-03	4.10E-01	1.00E-02	2.60E-01	1.50E-02	4.00E-03	0.00E+00	1.50E-06	0.00E+00	1.60E-06
Start of Plume 1 Release (hr)	3.10	4.75	0.17	30.00	36.00	1.00	35.00		3.00		3.00
End of Plume 1 Release (hr)	4.00	6.00	1.50	32.00	40.00	2.50	45.00		4.00		4.50
Total Plume 2 Release Fraction	8.00E-02	1.10E-01	2.70E-01	2.20E-01	5.00E-02	1.10E-02	8.00E-03	3.10E-02	2.00E-07	9.80E-05	1.00E-07
Start of Plume 2 Release (hr)	4.00	6.00	1.50	32.00	46.00	2.50	45.00	28.00	4.00	32.00	4.50
End of Plume 2 Release (hr)	6.00	14.00	4.00	34.00	50.00	7.00	50.00	32.00	6.00	38.00	8.00
Total Plume 3 Release Fraction	2.40E-01	3.80E-02	2.00E-02	7.00E-02	5.00E-02	4.40E-02	4.50E-02	9.00E-03	6.00E-07	0.00E+00	0.00E+00
Start of Plume 3 Release (hr)	6.00	14.00	6.90	38.00	50.00	7.00	50.00	32.00	22.00		
End of Plume 3 Release (hr)	16.00	24.00	7.90	45.00	60.00	17.00	60.00	38.00	32.00		

TABLE E.3-6
HCGS SOURCE TERM SUMMARY

	RELEASE CATEGORY										
	H/E-HP	H/E-LP	H/E-BOC	H / I	H / L	M / E	M / I	M / L	L/E LL/E L/I LL/I	L/L LL/L	INTACT
Bin Frequency	1.83E-07	7.15E-08	1.30E-07	9.70E-07	8.34E-08	3.48E-07	2.16E-07	0.00E+00	2.68E-07	2.39E-07	1.93E-06
MAAP Case	HC070500	HC070504	HC070524	HC070509	HC070515	HC070519	HC070516	HC070502	HC070503	HC070505	HC070525A
Run Duration	38 hr	38 hr	38 hr	72 hr	84 hr	38 hr	84 hr	38 hr	38 hr	38 hr	38 hr
Time after Scram when GE is declared (1)	30 min.	30 min.	30 min.	20 hr	20 hr	50 min.	20 hr	30 min.	30 min.	30 min.	30 min.
Fission Product Group:											
3) TeO2											
Total Release Fraction	2.40E-01	4.50E-02	4.70E-01	7.90E-02	1.10E-01	3.50E-02	1.50E-02	2.20E-02	4.60E-07	4.90E-05	5.20E-07
Total Plume 1 Release Fraction	3.00E-02	1.00E-03	4.60E-01	2.60E-02	9.00E-02	8.00E-03	1.20E-03	0.00E+00	2.20E-07	0.00E+00	3.50E-07
Start of Plume 1 Release (hr)	3.10	4.75	0.17	30.00	36.00	1.00	35.00		3.00		3.00
End of Plume 1 Release (hr)	4.00	6.00	1.50	32.00	40.00	2.50	45.00		4.00		4.50
Total Plume 2 Release Fraction	2.10E-01	2.30E-02	1.00E-02	4.50E-02	1.00E-02	1.00E-03	2.00E-04	1.20E-02	2.00E-07	4.90E-05	1.50E-07
Start of Plume 2 Release (hr)	4.00	6.00	1.50	32.00	46.00	2.50	45.00	28.00	4.00	32.00	4.50
End of Plume 2 Release (hr)	6.00	14.00	4.00	34.00	50.00	7.00	50.00	32.00	6.00	38.00	8.00
Total Plume 3 Release Fraction	0.00E+00	2.10E-02	0.00E+00	8.00E-03	1.00E-02	2.60E-02	1.36E-02	1.00E-02	4.00E-08	0.00E+00	2.00E-08
Start of Plume 3 Release (hr)		14.00		38.00	50.00	7.00	50.00	32.00	22.00		8.00
End of Plume 3 Release (hr)		24.00		45.00	60.00	17.00	60.00	38.00	32.00		18.00
4) SrO											
Total Release Fraction	1.70E-02	1.40E-02	2.00E-02	5.90E-03	8.00E-03	1.40E-02	6.10E-03	2.10E-03	3.60E-11	7.20E-10	3.00E-11
Total Plume 1 Release Fraction	6.00E-03	1.30E-02	5.00E-03	0.00E+00	4.00E-04	0.00E+00	0.00E+00	0.00E+00	3.50E-11	7.20E-10	3.00E-11
Start of Plume 1 Release (hr)	3.10	4.75	0.17		36.00				3.00	4.75	3.00
End of Plume 1 Release (hr)	4.00	6.00	1.50		40.00				4.00	5.50	4.50
Total Plume 2 Release Fraction	1.10E-02	1.00E-03	0.00E+00	1.00E-04	7.60E-03	1.40E-02	6.10E-03	1.70E-03	0.00E+00	0.00E+00	0.00E+00
Start of Plume 2 Release (hr)	4.00	6.00		32.00	46.00	2.50	45.00	28.00			
End of Plume 2 Release (hr)	6.00	14.00		34.00	50.00	7.00	50.00	32.00			
Total Plume 3 Release Fraction	0.00E+00	0.00E+00	1.50E-02	5.80E-03	0.00E+00	0.00E+00	0.00E+00	4.00E-04	1.00E-12	0.00E+00	0.00E+00
Start of Plume 3 Release (hr)			6.90	38.00				32.00	22.00		
End of Plume 3 Release (hr)			7.90	45.00				38.00	32.00		

TABLE E.3-6
HCGS SOURCE TERM SUMMARY

	RELEASE CATEGORY										
	H/E-HP	**H/E-LP**	**H/E-BOC**	**H / I**	**H / L**	**M / E**	**M / I**	**M / L**	**L/E LL/E L/I LL/I**	**L/L LL/L**	**INTACT**
Bin Frequency	1.83E-07	7.15E-08	1.30E-07	9.70E-07	8.34E-08	3.48E-07	2.16E-07	0.00E+00	2.68E-07	2.39E-07	1.93E-06
MAAP Case	HC070500	HC070504	HC070524	HC070509	HC070515	HC070519	HC070516	HC070502	HC070503	HC070505	HC070525A
Run Duration	38 hr	38 hr	38 hr	72 hr	84 hr	38 hr	84 hr	38 hr	38 hr	38 hr	38 hr
Time after Scram when GE is declared (1)	30 min.	30 min.	30 min.	20 hr	20 hr	50 min.	20 hr	30 min.	30 min.	30 min.	30 min.
Fission Product Group:											
5) MoO2											
Total Release Fraction	2.60E-06	8.10E-07	2.20E-02	1.60E-03	8.20E-04	8.60E-05	7.90E-06	3.60E-09	3.50E-11	1.10E-11	2.40E-11
Total Plume 1 Release Fraction	2.10E-06	4.20E-07	2.20E-02	1.10E-03	2.00E-04	7.90E-05	7.50E-06	2.00E-10	3.20E-11	2.00E-12	2.40E-11
Start of Plume 1 Release (hr)	3.10	4.75	0.17	30.00	36.00	1.00	35.00	22.00	3.00	4.75	3.00
End of Plume 1 Release (hr)	4.00	6.00	1.50	32.00	40.00	2.50	45.00	25.00	4.00	5.50	4.50
Total Plume 2 Release Fraction	0.00E+00	3.00E-08	0.00E+00	5.00E-04	6.20E-04	7.00E-06	4.00E-07	1.00E-10	0.00E+00	9.00E-12	0.00E+00
Start of Plume 2 Release (hr)		6.00		32.00	46.00	2.50	45.00	28.00		32.00	
End of Plume 2 Release (hr)		14.00		34.00	50.00	7.00	50.00	32.00		38.00	
Total Plume 3 Release Fraction	5.00E-07	3.60E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.30E-09	3.00E-12	0.00E+00	0.00E+00
Start of Plume 3 Release (hr)	6.00	14.00						32.00	22.00		
End of Plume 3 Release (hr)	16.00	24.00						38.00	32.00		
6) CsOH											
Total Release Fraction	3.30E-01	1.40E-01	4.20E-01	6.40E-02	1.30E-01	1.50E-01	4.50E-02	6.50E-02	2.80E-06	1.10E-03	9.30E-07
Total Plume 1 Release Fraction	6.00E-02	8.00E-04	3.70E-01	8.00E-03	6.00E-02	6.00E-03	1.00E-03	0.00E+00	2.00E-07	0.00E+00	3.70E-07
Start of Plume 1 Release (hr)	3.10	4.75	0.17	30.00	36.00	1.00	35.00		3.00		3.00
End of Plume 1 Release (hr)	4.00	6.00	1.50	32.00	40.00	2.50	45.00		4.00		4.50
Total Plume 2 Release Fraction	2.20E-01	1.10E-01	4.00E-02	3.20E-02	1.00E-02	2.00E-03	3.00E-03	3.80E-02	4.00E-07	1.10E-03	3.50E-07
Start of Plume 2 Release (hr)	4.00	6.00	1.50	32.00	46.00	2.50	45.00	28.00	4.00	32.00	4.50
End of Plume 2 Release (hr)	6.00	14.00	4.00	34.00	50.00	7.00	50.00	32.00	6.00	38.00	8.00
Total Plume 3 Release Fraction	5.00E-02	2.92E-02	1.00E-02	2.40E-02	6.00E-02	1.42E-01	4.10E-02	2.70E-02	2.20E-06	0.00E+00	2.10E-07
Start of Plume 3 Release (hr)	6.00	14.00	6.90	38.00	50.00	7.00	50.00	32.00	22.00		8.00
End of Plume 3 Release (hr)	16.00	24.00	7.90	45.00	60.00	17.00	60.00	38.00	32.00		18.00

TABLE E.3-6
HCGS SOURCE TERM SUMMARY

	RELEASE CATEGORY										
	H/E-HP	**H/E-LP**	**H/E-BOC**	**H / I**	**H / L**	**M / E**	**M / I**	**M / L**	**L/E LL/E L/I LL/I**	**L/L LL/L**	**INTACT**
Bin Frequency	1.83E-07	7.15E-08	1.30E-07	9.70E-07	8.34E-08	3.48E-07	2.16E-07	0.00E+00	2.68E-07	2.39E-07	1.93E-06
MAAP Case	HC070500	HC070504	HC070524	HC070509	HC070515	HC070519	HC070516	HC070502	HC070503	HC070505	HC070525A
Run Duration	38 hr	38 hr	38 hr	72 hr	84 hr	38 hr	84 hr	38 hr	38 hr	38 hr	38 hr
Time after Scram when GE is declared (1)	30 min.	30 min.	30 min.	20 hr	20 hr	50 min.	20 hr	30 min.	30 min.	30 min.	30 min.
Fission Product Group:											
7) BaO											
Total Release Fraction	7.50E-03	6.00E-03	3.90E-02	3.40E-03	5.20E-03	6.30E-03	2.70E-03	1.00E-03	9.50E-11	3.20E-10	7.20E-11
Total Plume 1 Release Fraction	2.40E-03	5.70E-03	3.30E-02	3.00E-04	9.00E-04	2.00E-04	0.00E+00	0.00E+00	8.90E-11	3.10E-10	7.20E-11
Start of Plume 1 Release (hr)	3.10	4.75	0.17	30.00	36.00	1.00			3.00	4.75	3.00
End of Plume 1 Release (hr)	4.00	6.00	1.50	32.00	40.00	2.50			4.00	5.50	4.50
Total Plume 2 Release Fraction	5.10E-03	3.00E-04	0.00E+00	6.00E-04	4.30E-03	6.10E-03	2.70E-03	8.00E-04	0.00E+00	1.00E-11	0.00E+00
Start of Plume 2 Release (hr)	4.00	6.00		32.00	46.00	2.50	45.00	28.00		32.00	
End of Plume 2 Release (hr)	6.00	14.00		34.00	50.00	7.00	50.00	32.00		38.00	
Total Plume 3 Release Fraction	0.00E+00	0.00E+00	6.00E-03	2.50E-03	0.00E+00	0.00E+00	0.00E+00	2.00E-04	6.00E-12	0.00E+00	0.00E+00
Start of Plume 3 Release (hr)			6.90	38.00				32.00	22.00		
End of Plume 3 Release (hr)			7.90	45.00				38.00	32.00		
8) La2O3											
Total Release Fraction	1.20E-03	1.50E-03	3.10E-03	6.90E-04	4.70E-04	1.60E-03	3.10E-04	1.40E-05	2.60E-12	7.60E-11	1.70E-12
Total Plume 1 Release Fraction	4.00E-04	1.50E-03	4.00E-04	0.00E+00	1.00E-05	0.00E+00	0.00E+00	0.00E+00	2.40E-12	7.60E-11	1.70E-12
Start of Plume 1 Release (hr)	3.10	4.75	0.17		36.00				3.00	4.75	3.00
End of Plume 1 Release (hr)	4.00	6.00	1.50		40.00				4.00	5.50	4.50
Total Plume 2 Release Fraction	8.00E-04	0.00E+00	0.00E+00	5.00E-05	4.60E-04	1.60E-03	3.10E-04	1.00E-05	0.00E+00	0.00E+00	0.00E+00
Start of Plume 2 Release (hr)	4.00			32.00	46.00	2.50	45.00	28.00			
End of Plume 2 Release (hr)	6.00			34.00	50.00	7.00	50.00	32.00			
Total Plume 3 Release Fraction		0.00E+00	2.70E-03	6.40E-04	0.00E+00	0.00E+00	0.00E+00	4.00E-06	2.00E-13	0.00E+00	0.00E+00
Start of Plume 3 Release (hr)			6.90	38.00				32.00	22.00		
End of Plume 3 Release (hr)			7.90	45.00				38.00	32.00		

TABLE E.3-6
HCGS SOURCE TERM SUMMARY

	RELEASE CATEGORY										
	H/E-HP	H/E-LP	H/E-BOC	H / I	H / L	M / E	M / I	M / L	L/E LL/E L/I LL/I	L/L LL/L	INTACT
Bin Frequency	1.83E-07	7.15E-08	1.30E-07	9.70E-07	8.34E-08	3.48E-07	2.16E-07	0.00E+00	2.68E-07	2.39E-07	1.93E-06
MAAP Case	HC070500	HC070504	HC070524	HC070509	HC070515	HC070519	HC070516	HC070502	HC070503	HC070505	HC070525A
Run Duration	38 hr	38 hr	38 hr	72 hr	84 hr	38 hr	84 hr	38 hr	38 hr	38 hr	38 hr
Time after Scram when GE is declared (1)	30 min.	30 min.	30 min.	20 hr	20 hr	50 min.	20 hr	30 min.	30 min.	30 min.	30 min.
Fission Product Group:											
9) CeO2											
Total Release Fraction	1.60E-02	1.30E-02	2.30E-02	8.20E-03	5.00E-03	1.50E-02	3.70E-03	6.80E-04	2.10E-11	6.50E-10	1.40E-11
Total Plume 1 Release Fraction	4.00E-03	1.30E-02	1.00E-03	0.00E+00	1.00E-04	0.00E+00	0.00E+00	0.00E+00	2.00E-11	6.50E-10	1.40E-11
Start of Plume 1 Release (hr)	3.10	4.75	0.17		36.00				3.00	4.75	3.00
End of Plume 1 Release (hr)	4.00	6.00	1.50		40.00				4.00	5.50	4.50
Total Plume 2 Release Fraction	1.20E-02	0.00E+00	0.00E+00	1.00E-04	4.90E-03	1.50E-02	3.70E-03	5.10E-04	0.00E+00	0.00E+00	0.00E+00
Start of Plume 2 Release (hr)	4.00			32.00	46.00	2.50	45.00	28.00			
End of Plume 2 Release (hr)	6.00			34.00	50.00	7.00	50.00	32.00			
Total Plume 3 Release Fraction	0.00E+00	0.00E+00	2.20E-02	8.10E-03	0.00E+00	0.00E+00	0.00E+00	1.70E-04	1.00E-12	0.00E+00	0.00E+00
Start of Plume 3 Release (hr)			6.90	38.00				32.00	22.00		
End of Plume 3 Release (hr)			7.90	45.00				38.00	32.00		
10) Sb											
Total Release Fraction	4.10E-01	8.10E-02	7.30E-01	7.60E-02	8.30E-02	1.00E-01	2.90E-02	5.00E-02	1.00E-06	9.70E-06	4.90E-09
Total Plume 1 Release Fraction	3.00E-02	4.10E-02	5.80E-01	1.00E-04	4.00E-02	1.00E-02	1.00E-03	0.00E+00	0.00E+00	0.00E+00	4.90E-09
Start of Plume 1 Release (hr)	3.10	4.75	0.17	30.00	36.00	1.00	35.00				3.00
End of Plume 1 Release (hr)	4.00	6.00	1.50	32.00	40.00	2.50	45.00				4.50
Total Plume 2 Release Fraction	1.50E-01	2.00E-02	8.00E-02	1.00E-04	2.90E-02	5.00E-02	2.30E-02	1.80E-02	0.00E+00	9.70E-06	0.00E+00
Start of Plume 2 Release (hr)	4.00	6.00	1.50	32.00	46.00	2.50	45.00	28.00		32.00	
End of Plume 2 Release (hr)	6.00	14.00	4.00	34.00	50.00	7.00	50.00	32.00		38.00	
Total Plume 3 Release Fraction	2.30E-01	2.00E-02	7.00E-02	7.58E-02	1.40E-02	4.00E-02	5.00E-03	3.20E-02	1.00E-06	0.00E+00	0.00E+00
Start of Plume 3 Release (hr)	6.00	14.00	6.90	38.00	50.00	7.00	50.00	32.00	22.00		
End of Plume 3 Release (hr)	16.00	24.00	7.90	45.00	60.00	17.00	60.00	38.00	32.00		
11) Te2											
Total Release Fraction	5.00E-02	2.50E-03	1.30E-03	1.70E-03	9.20E-04	2.80E-03	2.40E-04	3.30E-02	4.10E-09	1.00E-08	1.70E-10
Total Plume 1 Release Fraction	1.70E-02	2.20E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.00E-10	0.00E+00	1.70E-10
Start of Plume 1 Release (hr)	3.10	4.75							3.00		3.00

TABLE E.3-6
HCGS SOURCE TERM SUMMARY

	RELEASE CATEGORY										
	H/E-HP	**H/E-LP**	**H/E-BOC**	**H / I**	**H / L**	**M / E**	**M / I**	**M / L**	**L/E LL/E L/I LL/I**	**L/L LL/L**	**INTACT**
Bin Frequency	1.83E-07	7.15E-08	1.30E-07	9.70E-07	8.34E-08	3.48E-07	2.16E-07	0.00E+00	2.68E-07	2.39E-07	1.93E-06
MAAP Case	HC070500	HC070504	HC070524	HC070509	HC070515	HC070519	HC070516	HC070502	HC070503	HC070505	HC070525A
Run Duration	38 hr	38 hr	38 hr	72 hr	84 hr	38 hr	84 hr	38 hr	38 hr	38 hr	38 hr
Time after Scram when GE is declared (1)	30 min.	30 min.	30 min.	20 hr	20 hr	50 min.	20 hr	30 min.	30 min.	30 min.	30 min.
Fission Product Group:											
End of Plume 1 Release (hr)	4.00	6.00							4.00		4.50
Total Plume 2 Release Fraction	1.30E-02	2.00E-04	0.00E+00	0.00E+00	8.50E-04	2.40E-03	2.30E-04	1.60E-02	0.00E+00	1.00E-08	0.00E+00
Start of Plume 2 Release (hr)	4.00	6.00			46.00	2.50	45.00	28.00		32.00	
End of Plume 2 Release (hr)	6.00	14.00			50.00	7.00	50.00	32.00		38.00	
Total Plume 3 Release Fraction	2.00E-02	1.00E-04	1.30E-03	1.70E-03	7.00E-05	4.00E-04	1.00E-05	1.70E-02	3.90E-09	0.00E+00	0.00E+00
Start of Plume 3 Release (hr)	6.00	14.00	6.90	38.00	50.00	7.00	50.00	32.00	22.00		
End of Plume 3 Release (hr)	16.00	24.00	7.90	45.00	60.00	17.00	60.00	38.00	32.00		
12) UO2											
Total Release Fraction	8.40E-05	9.40E-05	1.70E-04	4.60E-05	2.80E-05	1.00E-04	2.00E-05	2.30E-06	1.40E-14	4.90E-12	1.20E-14
Total Plume 1 Release Fraction	2.30E-05	9.00E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.40E-14	4.90E-12	1.20E-14
Start of Plume 1 Release (hr)	3.10	4.75							3.00	4.75	3.00
End of Plume 1 Release (hr)	4.00	6.00							4.00	5.50	4.50
Total Plume 2 Release Fraction	5.90E-05	4.00E-06	0.00E+00	0.00E+00	2.70E-05	9.80E-05	2.00E-05	1.00E-06	0.00E+00	0.00E+00	0.00E+00
Start of Plume 2 Release (hr)	4.00	6.00			46.00	2.50	45.00	28.00			
End of Plume 2 Release (hr)	6.00	14.00			50.00	7.00	50.00	32.00			
Total Plume 3 Release Fraction	0.00	0.00E+00	1.70E-04	4.60E-05	1.00E-06	2.00E-05	0.00E+00	1.30E-06	0.00E+00	0.00E+00	0.00E+00
Start of Plume 3 Release (hr)			6.90	38.00	50.00	7.00		32.00			
End of Plume 3 Release (hr)			7.90	45.00	60.00	17.00		38.00			

(1) General Emergency declaration estimated from Hope Creek Emergency Classification Guide (PSEG 2007).

TABLE E.3-7
MACCS2 BASE CASE MEAN RESULTS

SOURCE TERM	RELEASE CATEGORY	DOSE (P-REM)	OFFSITE ECONOMIC COST ($)	FREQ. (/YR)[1]	DOSE-RISK (P-REM/YR)	OECR ($/YR)
ST1	H / E – HP	1.82E+07	1.15E+11	1.830E-07	3.33E+00	2.10E+04
ST2	H / E – LP	1.38E+07	9.63E+10	7.152E-08	9.87E-01	6.89E+03
ST3	H / E – BOC	2.34E+07	1.15E+11	1.302E-07	3.05E+00	1.50E+04
ST4	H / I	8.75E+06	6.41E+10	9.697E-07	8.49E+00	6.22E+04
ST5	H / L	1.10E+07	9.23E+10	8.336E-08	9.17E-01	7.69E+03
ST6	M / E	1.31E+07	9.17E+10	3.477E-07	4.55E+00	3.19E+04
ST7	M / I	6.34E+06	4.73E+10	2.164E-07	1.37E+00	1.02E+04
ST8	M / L	6.38E+06	5.35E+10	0.000E+00	0.00E+00	0.00E+00
ST9	L/E, L/I, LL/E, LL/I	6.44E+03	2.54E+05	2.677E-07	1.72E-03	6.80E-02
ST10	L/L, LL/L	6.87E+05	7.41E+08	2.392E-07	1.64E-01	1.77E+02
ST11	INTACT	1.01E+03	3.63E+04	1.933E-06	1.95E-03	7.02E-02
			FREQUENCY WEIGHTED TOTALS	**4.44E-06**	**2.29E+01**	**1.55E+05**

[1] Release frequencies were calculated at a truncation limit of 5E-11/yr.

TABLE E.5-1
LEVEL 1 IMPORTANCE LIST REVIEW

EVENT NAME	PROBABILITY	RISK REDUCTION WORTH	DESCRIPTION	POTENTIAL SAMAS
ADS-XHE-OK-INHIB	1.00E+00	1.399	OPERATOR SUCCESSFULLY INHIBITS ADS WITH NO HP INJECTION (NON-ATWS)	BWROG recommends inhibiting ADS during normal operation, therefore, install alternate injection system capable of operating at high pressures. (SAMA 1)
%IE-SWS	1.79E-04	1.220	LOSS OF SERVICE WATER INITIATING EVENT	This initiator event is a compilation of industry and plant-specific data. (No specific SAMA identified)
NR-IE-SWS	1.00E+00	1.220	NONRECOVERY OF %IE-SWS	Provide a back-up air compressor to supply AOVs with an alternate air source. (SAMA 3) Provide the ability to cross-tie RHR pumps trains. (SAMA 4)
NR-U1X-DEP-SRV	3.00E-04	1.215	FAILURE TO DEPRESSURIZE WITH SRV W/O HIGH PRES. INJ.	This event is tied to a similar scenario that involves inhibiting ADS. Consider installing alternate injection system capable of operating at high pressures. This particular event may be mitigated via SAMA 1.
RHS-REPAIR-TR	3.50E-01	1.204	REPAIR/RECOVERY OF RHR FOR LOSS OF DHR EVENTS (TRANSIENT EVENTS)	See SAMA 4
%IE-TE	2.37E-02	1.188	LOSS OF OFFSITE POWER INITIATING EVENT	This initiator event is a compilation of industry and plant-specific data. (No specific SAMA identified)
%IE-MS	1.46E+00	1.161	MANUAL SHUTDOWN INITIATING EVENT	This initiating event is tied to plant-specific operating experience. (No specific SAMA identified)

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EVENT NAME	PROBABILITY	RISK REDUCTION WORTH	DESCRIPTION	POTENTIAL SAMAS
%IE-TT	7.03E-01	1.130	TURBINE TRIP WITH BYPASS	This initiator event represents a protective trip based on transients associated with balance of plant systems that are generally not safety-related. The maintenance rule process and other performance indicators provide a method for minimizing this initiator frequency. (No specific SAMA identified)
NR-XTIE-EDG	1.00E+00	1.088	FAILURE TO CROSS-TIE DIESEL GENERATOR	Improve procedural use of gas turbine generator to restore onsite emergency AC power sources. (SAMA 5)
LOOP-IE-SW	2.10E-01	1.085	COND. PROBABILITY DUE TO WEATHER RELATED LOOP EVENT	See SAMA 5
%IE-S2-WA	6.20E-04	1.064	SMALL LOCA - WATER (BELOW TAF)	This initiator event is a compilation of industry and plant-specific data. (No specific SAMA identified)
SAC-XHE-MC-DF01	8.00E-05	1.058	DEPENDENT FAILURE OF MISCAL. OF TEMP CONTROLLER HV-2457S	The miscalibration of temp controller HV-2457S during a LOOP event may result in SW bypass of the SACS heat exchangers. Bypassing the SACS heat exchangers would increase temperatures in the SACS system and compromise the ability of the RHR HXs to remove heat from the RPV, leading to core damage. The low probability of this event combined with existing procedural guidance for calibrating this controller suggests very limited opportunity for improvement. (No specific SAMA identified)

TABLE E.5-1
LEVEL 1 IMPORTANCE LIST REVIEW

EVENT NAME	PROBABILITY	RISK REDUCTION WORTH	DESCRIPTION	POTENTIAL SAMAS
%IE-S2-ST	6.20E-04	1.053	SMALL LOCA - STEAM (ABOVE TAF)	This initiator event is a compilation of industry and plant-specific data. (No specific SAMA identified)
OSPR20HR-SW	1.33E-01	1.052	FAILURE TO RECOVER OSP WITHIN 20 HRS (SW RELATED LOOP EVENT)	This event appears in conjunction with failure to cross-tie diesel event and is addressed by SAMA 5.
NR-S1X-DEP-SRV	3.20E-02	1.049	FAILURE TO MAN. DEPRESS. FOR A MED. LOCA W/NO HI PRESS. INJ.	Although operator training can be emphasized to reduce human error probability, based on the HEP analysis, significant credit is currently given to procedures and training, no further HEP enhancements are considered to lower event probability. (No specific SAMA identified)
RHS-MDP-TM-PB	1.58E-02	1.048	RHS PUMP TRAIN B IN TEST AND MAINT	This event can be mitigated through use of SAMAs 1, 4, and 8, since it appears with those related accident sequences.
SWS-XHE-RACS-UNI	1.00E+00	1.045	FAILURE TO ISOLATE LOCALLY A SW RUPTURE IN RACS COMPARTMENT	Replace existing manual valves with remotely-operated, auto-isolating MOVs to enhance isolation capability and eliminate the source of flooding. (SAMA 7)
%FLFPS-CR	1.10E-05	1.043	FPS RUPTURE OUTSIDE CONTROL ROOM	See SAMA 8
DW-SHELL-RUPT	4.50E-01	1.043	DRYWELL SHELL RUPTURE DISRUPTS INJECTION LINES AND FAILS RB SYS	This initiator event is a compilation of industry and plant-specific data. (No specific SAMA identified)

TABLE E.5-1
LEVEL 1 IMPORTANCE LIST REVIEW

EVENT NAME	PROBABILITY	RISK REDUCTION WORTH	DESCRIPTION	POTENTIAL SAMAS
FPS-XHE-CRISOL	1.00E+00	1.043	Operator fails to secure FPS given CR area rupture	This HRE represents an internal flooding scenario that disables various safety-related components. Mitigation of this event can be accomplished by changing the existing FPS to a dry-pipe system. (SAMA 8)
MCR-PHE-DOOR	5.00E-01	1.043	MCR DOOR FAILS DUE TO WATER PRESSURE	See SAMA 8
HPI-TDP-FS-OP204	1.39E-02	1.042	HPCI TDP FAILS TO START	See SAMA 1
RPCDRPS-MECHFCC	2.10E-06	1.042	MECHANICAL SCRAM FAILURE	This is a low probability event based on sparse industry data. (No specific SAMA identified)
XHOS-RIVER-LT70	6.90E-01	1.042	RIVER TEMPERATURE IS LESS THAN 70 F	This event is based on environmental conditions specific to the plant site. (No specific SAMA identified)
%IE-TC	9.33E-02	1.040	LOSS OF CONDENSER VACUUM	This initiator event is a compilation of industry and plant-specific data. (No specific SAMA identified)
DCP-XHE-PORTA	6.20E-02	1.031	FAILURE TO CROSS TIE BUS TO BATTERY CHARGER PORTABLE SUPPLY	See SAMA 5
RX-FWR-POR	2.30E-03	1.029	DEP OP ACT: FAIL TO INITIATE FW CNTRL AND PORTABLE GENERATOR ALIGNMENT	See SAMA 5
CAC-AOV-CC-11541	1.11E-03	1.028	PNUEMATIC SUPPLY TO HV-11541 FAILS	See SAMA 4
CAC-AOV-CC-4964	1.11E-03	1.028	PNEUMATIC SUPPLY TO HV-4964 FAILS	See SAMA 4

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LEVEL 1 IMPORTANCE LIST REVIEW

EVENT NAME	PROBABILITY	RISK REDUCTION WORTH	DESCRIPTION	POTENTIAL SAMAS
CAC-XHE-FO-LVENT	6.20E-02	1.028	LOCAL VENTING THRU 12" LINE FAILS	See SAMA 4
CSS-STR-PL-A	8.36E-03	1.027	CSS PUMP A SUCTION STRAINERS PLUGGED IN STANDBY	Consider alternate design of CSS suction strainer to mitigate plugging. (SAMA 15)
CSS-STR-PL-B	8.36E-03	1.027	CSS PUMP B SUCTION STRAINERS PLUGGED IN STANDBY	See SAMA 15
CSS-STR-PL-C	8.36E-03	1.027	CSS PUMP C SUCTION STRAINERS PLUGGED IN STANDBY	See SAMA 15
CSS-STR-PL-D	8.36E-03	1.027	CSS PUMP D SUCTION STRAINERS PLUGGED IN STANDBY	See SAMA 15
NRHVCSWGR24-01	4.10E-03	1.027	Fail to restore SWGR room cooling	Consider replacing one of the SWGR room cooling fans with a different design so as to eliminate common cause failure of all fans. (SAMA 16)
QUVISL	1.00E+00	1.027	ALTERNATE MAKEUP SOURCES INADEQUATE (ISLOCA)	See SAMA 1
VIS-FAN-FS-DF01	1.08E-05	1.027	CCF FAILURE FANS A THRU DV503 FAIL TO START	Consider replacing one of the SW pump room supply fans with a different design so as to eliminate common cause failure of all fans. (SAMA 17)
VIS-FAN-FS-DF12	1.08E-05	1.027	CCF FAILURE FANS A THRU DV504 FAIL TO START	Consider replacing one of the SW pump room return fans with a different design so as to eliminate common cause failure of all fans. (SAMA 18)

TABLE E.5-1
LEVEL 1 IMPORTANCE LIST REVIEW

EVENT NAME	PROBABILITY	RISK REDUCTION WORTH	DESCRIPTION	POTENTIAL SAMAS
VISL	1.00E+00	1.027	LOW PRESSURE MAKEUP UNAVAILABLE (ISLOCA)	See SAMA 1
XHOS-STBY-AP502LT	5.00E-01	1.027	PUMP SSW AP502 IN STANDBY WITH 2 PUMPS OPERATING	This event represents the normal configuration of SSW pumps. Specific SAMAs associated with this system are addressed elsewhere. (No specific SAMA identified)
XHOS-STBY-CP502LT	5.00E-01	1.027	PUMP SSW CP502 IN STANDBY WITH 2 PUMPS OPERATING	This event represents the normal configuration of SSW pumps. Specific SAMAs associated with this system are addressed elsewhere. (No specific SAMA identified)
%IE-ISLOCAD	1.63E-05	1.026	ISLOCA INITIATOR FOR ECCS DISCHARGE PATHS	This initiator event is a compilation of industry and plant-specific data. (No specific SAMA identified)
UISLOCA	1.00E+00	1.026	HPCI/RCIC UNAVAILABLE FOR ISLOCA (LARGE RUPTURE OR NO EARLY ISOLATION)	See SAMA 1
IS1L	4.20E-01	1.025	SYSTEM ISOLATION FAILS GIVEN LEAKAGE	This is a conditional probability based on an initial failure mechanism. The probability is based on industry and operating experience. (No specific SAMA identified)
LEAKD	5.00E-01	1.025	PIPE LEAKAGE GIVEN OVERPRESSURIZATION IN SDC DISCHARGE LINES	This is a conditional probability based on an initial failure mechanism. The probability is based on industry and operating experience. (No specific SAMA identified)
VIS-FAN-FR-DF01	9.90E-06	1.025	CCF FAILURE FANS A THRU DV503 FAIL TO RUN	See SAMA 17

TABLE E.5-1
LEVEL 1 IMPORTANCE LIST REVIEW

EVENT NAME	PROBABILITY	RISK REDUCTION WORTH	DESCRIPTION	POTENTIAL SAMAS
VIS-FAN-FR-DF12	9.90E-06	1.025	CCF FAILURE FANS A THRU DV504 FAIL TO RUN	See SAMA 18
CAC-SOV-CC-11541	9.54E-04	1.024	SOLENOID VALVE SV-11541 FAILS TO OPEN.	See SAMA 4
CAC-SOV-CC-4964	9.54E-04	1.024	SOLENOID VALVE 4964 FAILS TO OPEN.	See SAMA 4
DGS-DGN-FS-BG400	1.31E-02	1.024	REPAIR/RECOVERY OF RHR FOR LOSS OF DHR EVENTS (LOCA EVENTS)	See SAMA 5
SLC-XHE-E-LVL	4.60E-01	1.024	FAIL TO CONTROL LEVEL EARLY DURING ATWS SEQUENCE	Adequate training and procedures already exist. High failure probability is due to the short response time involved. Further training and/or procedure enhancement will not reduce the failure probability. (No specific SAMA identified)
ACP-BAC-HV-RMCLG	9.00E-01	1.023	FAILURE OF EQUIPMENT GIVEN NO SWG ROOM COOLING	Although this is a conditional probability based on an initial failure mechanism, SAMA 16 may help mitigate the associated accident sequence.
DGS-DGN-FS-DG400	1.31E-02	1.023	DIVISION D DIESEL 1DG400 FAILS TO START	See SAMA 5
%FL-FPS-5302	6.62E-06	1.022	INT. FLOOD OUTSIDE LOWER RELAY ROOM	This initiator event is a compilation of industry and plant-specific data. (No specific SAMA identified)
FPS-XHE-5302IS	5.00E-01	1.022	OP. FAILS TO SECURE FPS GIVEN LCER AREA RUPTURE (EARLY)	See SAMA 8

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EVENT NAME	PROBABILITY	RISK REDUCTION WORTH	DESCRIPTION	POTENTIAL SAMAS
HPI-TDP-TM-OP204	1.09E-02	1.022	FAILURE TO ISOLATE LOCALLY A SW RUPTURE IN RACS COMPARTMENT	See SAMA 1
LCER-PHE-DOOR	1.00E+00	1.022	LCER DOOR FAILS DUE TO WATER PRESSURE	See SAMA 8
DCP-BDC-ST-DF01	3.87E-08	1.021	CCF FAILURE 125VDC BUSES 10D410 - 20 - 30 - & 40	Based on low contribution to L1 and L2 and engineering judgment, the anticipated implementation cost of hardware mods associated with mitigating this event would likely exceed the expected cost-risk benefit. (No specific SAMA identified)
%IE-TM	5.62E-02	1.020	MSIV CLOSURE	This initiating event is tied to plant-specific operating experience. (No specific SAMA identified)
RX-FW-ADS	5.10E-05	1.020	COND. PROB. OF SMALL RECIRC SEAL LOCA GIVEN SBO	See SAMA 1
VSW-FAN-FR-DF12	9.90E-06	1.020	CCF FAILURE FANS A THRU DVH401 FAIL TO RUN	Consider replacing one of the SWGR room cooling fans with a different design so as to eliminate common cause failure of all fans. (SAMA 16)
XHOS-STBY-DP502LT	5.00E-01	1.020	PUMP SSW DP502 IN STANDBY WITH 2 PUMPS OPERATING	This event represents the normal configuration of SSW pumps. Specific SAMAs associated with this system are addressed elsewhere. (No specific SAMA identified)

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LEVEL 1 IMPORTANCE LIST REVIEW

EVENT NAME	PROBABILITY	RISK REDUCTION WORTH	DESCRIPTION	POTENTIAL SAMAS
CSS-MDP-TM-PAC	1.36E-02	1.018	CSS PUMP TRAINS A AND C IN TEST AND MAINT	Based on low contribution to L1 risk and engineering judgment, the anticipated implementation cost of hardware mods associated with mitigating this event would likely exceed the expected cost-risk benefit. (No specific SAMA identified)
CSS-MDP-TM-PBD	1.36E-02	1.018	CSS PUMP TRAINS B AND D IN TEST AND MAINT	Based on low contribution to L1 risk and engineering judgment, the anticipated implementation cost of hardware mods associated with mitigating this event would likely exceed the expected cost-risk benefit. (No specific SAMA identified)
NR-VENT-5-03	4.10E-04	1.018	FAILURE TO INITIATE CONT. VENT. GIVEN SPC HARDWARE FAILURE	Although adequate training and procedures already exist, SAMA 4 would help to mitigate the associated accident sequence. Given the low RRW value of <1.02, this modification may not be cost beneficial if implementation costs are greater than $500K.
RX-ADS-SW	2.25E-05	1.018	DEP OP ACT: FAIL TO INITIATE ADS AND START SW	This basic event appears in conjuction with ADS-XHE-OK-INHIB, therefore SAMA 1 applies to this event as well.
%FLSWAB-RACS-U	7.60E-08	1.017	FREQ OF COMMON HEADER TO RACS RUPTURE (UNISOLABLE)	Based on low contribution to L1 risk and engineering judgment, the anticipated implementation cost of hardware mods associated with mitigating this event would likely exceed the expected cost-risk benefit. (No specific SAMA identified)

TABLE E.5-1
LEVEL 1 IMPORTANCE LIST REVIEW

EVENT NAME	PROBABILITY	RISK REDUCTION WORTH	DESCRIPTION	POTENTIAL SAMAS
%IE-SACS	1.16E-04	1.017	LOSS OF SACS INITIATING EVENT	This initiating event is tied to plant-specific operating experience. Based on low contribution to L1 risk and engineering judgment, the anticipated implementation cost of hardware mods associated with mitigating this event would likely exceed the expected cost-risk benefit. (No specific SAMA identified)
NR-%IE-SACS	1.00E+00	1.017	NONRECOVERY OF %IE-SACS	Although contribution to L1 risk is low, SAMA 4 may provide some benefit in mitigating the associated accident sequence.Given the low RRW value of <1.02, this modification may not be cost beneficial if implementation costs are greater than $500K.
OSPR7HR-SW	2.80E-01	1.017	FAILURE TO RECOVER OSP WITHIN 7 HRS (SW RELATED LOOP EVENT)	Since this involves loss of long-term RHR, provide an independent means of alternate makeup to RPV. Possible suction sources are CST, RST and FPS. Possible use of an alternate diesel-driven pump combined with rapid depressurization. (SAMA 10)
%IE-TF	4.49E-02	1.016	FAILURE TO CNTRL PLANT USING REMOTE SHTDWN PANEL FLLWNG FPS RUPTURE OUTSIDE LWR	This initiator event is a compilation of industry and plant-specific data. (No specific SAMA identified)
DCP-EDG-PORTGEN	2.50E-02	1.016	FAILURE TO INITIATE RHR FOR DECAY HEAT REMOVAL WITHIN 20 HRS	See SAMA 5 Given the low RRW value of <1.02, this modification may not be cost beneficial if implementation costs are greater than $500K.

TABLE E.5-1
LEVEL 1 IMPORTANCE LIST REVIEW

EVENT NAME	PROBABILITY	RISK REDUCTION WORTH	DESCRIPTION	POTENTIAL SAMAS
NR-RHR-INIT-L	2.10E-06	1.016	FAILURE TO INITIATE RHR FOR DECAY HEAT REMOVAL WITHIN 20 HRS	Adequate training and procedures already exist. Further training and/or procedure enhancement will not reduce the failure probability. (No specific SAMA identified)
NR-RHRVENT-INIT	2.40E-01	1.016	FAIL TO INITIATE VENT GIVEN FAILURE TO INITIATE RHR IN SPC	This is a conditional failure probability based on HEP dependency analysis. Further training and/or procedure enhancement will not reduce the failure probability. (No specific SAMA identified)
RCI-TDP-FS-OP203	1.11E-02	1.016	CCF FAILURE OF HV-2457A AND B VALVES	See SAMA 1 Given the low RRW value of <1.02, this modification may not be cost beneficial if implementation costs are greater than $500K.
ESF-XHE-MC-DF01	8.00E-05	1.015	COMMON CAUSE MISCALIBRATION OF ALL ECCS PRESSURE TRANS.	This is a low probability event. Further training and/or procedure enhancement will not reduce the failure probability. (No specific SAMA identified)
MSOP-LVL1--H--	5.00E-01	1.015	RPV WATER LEVEL REQUIRED TO BE LOWERED BELOW LEVEL 1	This event represents a requirement (alignment flag) to lower RPV level below Level 1 to reduce reactor power during ATWS condition. (No specific SAMA identified)
MSOPMSIVINLKH--	9.20E-01	1.015	FAIL TO BYPASS THE LOW LEVEL INTERLOCK AT LVL 1 (-129")	Failure probability is based on HEP dependency analysis. Further training and/or procedure enhancement will not reduce the failure probability. This is an EOP-directed action that is practiced in the simulator as well as trained in the classroom. (No specific SAMA identified)

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LEVEL 1 IMPORTANCE LIST REVIEW

EVENT NAME	PROBABILITY	RISK REDUCTION WORTH	DESCRIPTION	POTENTIAL SAMAS
SAC-AOV-OO-DF01	2.26E-05	1.015	CCF FAILURE OF HV-2457A AND B VALVES	Consider replacing one AOV with an MOV to eliminate the CCF contribution of this event. However, based on low contribution to L1 risk and engineering judgment, the anticipated implementation cost of hardware mods associated with mitigating this event would likely exceed the expected cost-risk benefit. (No specific SAMA identified)
XHOS-STBY-BP502LT	5.00E-01	1.015	PUMP SSW BP502 IN STANDBY WITH 2 PUMPS OPERATING	This event represents a normal plant configuration lineup. (No specific SAMA identified)
DGS-DGN-TM-BG400	1.30E-02	1.014	DGS TRAIN BG400 IN TEST AND MAINT	See SAMA 5 Given the low RRW value of <1.02, this modification may not be cost beneficial if implementation costs are greater than $500K.
RHS-STR-PL-PB	4.21E-03	1.014	RHR SUCTION STRAINER B PLUGGED IN STANDBY	Based on low contribution to L1 risk and engineering judgment, the anticipated implementation cost of hardware mods associated with mitigating this event would likely exceed the expected cost-risk benefit. (No specific SAMA identified)
RPT-PIP-RP-SEALS	9.50E-01	1.014	COND. PROB. OF SMALL RECIRC SEAL LOCA GIVEN SBO	Consider replacing recirc seals with those of a more robust design that can withstand higher temps caused by loss of cooling. Based on low contribution to L1 risk and engineering judgment, the anticipated implementation cost of hardware mods associated with mitigating this event would likely exceed the expected cost-risk benefit. (No specific SAMA identified)

TABLE E.5-1
LEVEL 1 IMPORTANCE LIST REVIEW

EVENT NAME	PROBABILITY	RISK REDUCTION WORTH	DESCRIPTION	POTENTIAL SAMAS
%FLSWA-RACS-U	5.70E-08	1.013	FREQ. OF UNISOLABLE SW A PIPE RUPT IN RACS ROOM	Based on low contribution to L1 risk and engineering judgment, the anticipated implementation cost of hardware mods associated with mitigating this event would likely exceed the expected cost-risk benefit. (No specific SAMA identified)
%FLSWB-RACS-U	5.70E-08	1.013	FREQ. OF UNISOLABLE SW B PIPE RUPT. IN RACS ROOM	Based on low contribution to L1 risk and engineering judgment, the anticipated implementation cost of hardware mods associated with mitigating this event would likely exceed the expected cost-risk benefit. (No specific SAMA identified)
DGS-DGN-TM-DG400	1.30E-02	1.013	DGS TRAIN DG400 IN TEST AND MAINT	See SAMA 5 Given the low RRW value of <1.02, this modification may not be cost beneficial if implementation costs are greater than $500K.
HPI-TDP-FS-DFP01	3.17E-04	1.013	CCF FAILURE OF HPCI AND RCIC TDP TO START	Based on low contribution to L1 risk and engineering judgment, the anticipated implementation cost of hardware mods associated with mitigating this event would likely exceed the expected cost-risk benefit. (No specific SAMA identified) SAMA 1 may provide some benefit. Given the low RRW value of <1.02, this modification may not be cost beneficial if implementation costs are greater than $500K.
IE-LOOP-CND-L	2.40E-02	1.013	INADVERTENTLY OPEN SRV INITIATING EVENT	See SAMA 3 and 5Given the low RRW value of <1.02, this modification may not be cost beneficial if implementation costs are greater than $500K.

TABLE E.5-1
LEVEL 1 IMPORTANCE LIST REVIEW

EVENT NAME	PROBABILITY	RISK REDUCTION WORTH	DESCRIPTION	POTENTIAL SAMAS
RHR-XHE-RHR-INJ	1.00E-01	1.012	FAILURE TO ALIGN RHR MOV 17B LOCALLY FOR INJECTION	See SAMA 10 Given the low RRW value of <1.02, this modification may not be cost beneficial if implementation costs are greater than $500K.
CAC-LOG-NO-AC652	3.33E-03	1.011	LATE RPV WATER LEVEL CONTROL (CONDITIONAL)	See SAMA 4 Given the low RRW value of <1.02, this modification may not be cost beneficial if implementation costs are greater than $500K.
CAC-LOG-NO-DC652	3.33E-03	1.011	LOGIC CIRCUIT TO HV-4978 FAILS.	See SAMA 4 Given the low RRW value of <1.02, this modification may not be cost beneficial if implementation costs are greater than $500K.
NR-CSC-VSS-INIT	3.90E-02	1.011	SRVs SUCCESSFULLY RECLOSE ON REDUCED PRESSURE	See SAMA 1 Given the low RRW value of <1.02, this modification may not be cost beneficial if implementation costs are greater than $500K.
OSPR4HR-SW	3.61E-01	1.011	FAILURE TO RECOVER OFFSITE POWER WITHIN 4.5 HRS (SW RELATED EVENT)	See SAMA 5 Given the low RRW value of <1.02, this modification may not be cost beneficial if implementation costs are greater than $500K.
RHS-REPAIR-L	4.30E-01	1.011	REPAIR/RECOVERY OF RHR FOR LOSS OF DHR EVENTS (LOCA EVENTS)	See SAMA 4 Given the low RRW value of <1.02, this modification may not be cost beneficial if implementation costs are greater than $500K.
SRV-TNK-LK-TRANS	1.00E-04	1.011	FAILURE OF 13/14 ACCUMULATORS (LEAKAGE) (NON-SBO)	Based on engineering judgment, there would be no practical cost-beneficial SAMA capable of mitigating this particular low-probability event. (No specific SAMA identified)

TABLE E.5-1
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EVENT NAME	PROBABILITY	RISK REDUCTION WORTH	DESCRIPTION	POTENTIAL SAMAS
CSS-MDP-TM-PA	7.51E-03	1.010	CSS PUMP TRAIN A IN TEST AND MAINT	Based on low contribution to L1 risk and engineering judgment, the anticipated implementation cost of hardware mods associated with mitigating this event would likely exceed the expected cost-risk benefit. (No specific SAMA identified)
CSS-MDP-TM-PC	7.51E-03	1.010	CSS PUMP TRAIN C IN TEST AND MAINT	Based on low contribution to L1 risk and engineering judgment, the anticipated implementation cost of hardware mods associated with mitigating this event would likely exceed the expected cost-risk benefit. (No specific SAMA identified)
LOOP-IE-SWYD	4.03E-01	1.010	COND. PROBABILITY LOOP DUE TO SWYD EVENT	Although this is a conditional probability based on an initial failure mechanism, SAMA 5 may help mitigate the associated LOOP sequence. Given the low RRW value of <1.02, this modification may not be cost beneficial if implementation costs are greater than $500K.
CSS-MDP-TM-PB	7.51E-03	1.009	CSS PUMP TRAIN B IN TEST AND MAINT	Similar event that was previously addressed in L1 importance list.
CSS-MDP-TM-PD	7.51E-03	1.009	CSS PUMP TRAIN D IN TEST AND MAINT	Similar event that was previously addressed in L1 importance list.
RCI-TDP-TM-OP203	9.84E-03	1.009	RCI TURBINE TRAIN OP203 IN TEST AND MAINT	SAMA 1 applies to this event.
SLC-XHE-L-LVLCND	3.91E-02	1.009	LATE RPV WATER LEVEL CONTROL (CONDITIONAL)	This event was addressed in the L2 importance list.

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LEVEL 1 IMPORTANCE LIST REVIEW

EVENT NAME	PROBABILITY	RISK REDUCTION WORTH	DESCRIPTION	POTENTIAL SAMAS
SAC-MDP-TM-SSWA	2.30E-05	1.009	SAC-B IN MAINT. COINCIDENT WITH SSW A	This event appears with LOOP sequences; addressed by SAMA 5.
XHOS-RIVER-70TO80	1.90E-01	1.008	RIVER TEMPERATURE IS 70 TO 80 DEG F	This event is based on environmental data (no specific SAMA identified).
CAC-AOV-CC-DF01	2.00E-04	1.008	COMMON CAUSE FAILURE OF AIR OPERATED BUTTERFLY VALVES TO OPEN	This event appears in conjunction with RHS-REPAIR, which is addressed by SAMA 4.
RSP-XHE-CBFLD	4.00E-03	1.008	FAILURE TO CNTRL PLANT USING REMOTE SHTDWN PANEL FLLWNG FPS RUPTURE OUTSIDE LWR	SAMA 8 applies to this event.
NR-UV-WTLVL-20M	2.10E-02	1.008	FAILURE TO CONTROL RPV WATER LVL W/HIGH PRESS. INJ. SYS.	SAMA 1 applies to this event.
DGS-DGN-TM-ABCD	2.30E-05	1.007	COINCIDENT MAINTENANCE UNAVAILABILITY OF DG A, DG B, DG C, AND DG D	This event appears with LOOP sequences; addressed by SAMA 5.
HPI-STR-PL-DFLOC	1.00E-04	1.007	CCF PLUGGING OF ECCS SUCTION STRAINERS (LOCA)	SAMA 15 applies to this event.
DGS-DGN-FS-AG400	1.31E-02	1.007	DIVISION A DIESEL 1AG400 FAILS TO START	SAMA 5 applies to this event.
%IE-SORV2	2.44E-04	1.007	2 or More SORVs	SAMA 1 applies to this event.
RX-ADS-SW-HXDISH	1.50E-05	1.007	DEP HEP: FAILURE TO INITIATE ADS, SW PUMP, SWS HX VALVE	SAMA 1 applies to this event.
RCI-MOV-LK-ROOM	1.00E-01	1.007	PROBABILITY OF STEAM LEAK INTO RCI ROOM	This event appears with LOOP sequences; addressed by SAMA 5.

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EVENT NAME	PROBABILITY	RISK REDUCTION WORTH	DESCRIPTION	POTENTIAL SAMAS
FPS-XHE-ALIGN	5.80E-02	1.006	FAILURE TO ALIGN FPS FOR INJECTION IN TIME	This event was addressed in the L2 importance list.
OSPR30MIN-GR	8.25E-01	1.006	FAILURE TO RECOVER GRID LOOP W/IN 30 MIN.	SAMA 5 applies to this event.
RHS-MDP-TM-PA	1.58E-02	1.006	RHS PUMP TRAIN A IN TEST AND MAINT	SAMA 4 applies to this event.
NR-U1X-DEP-10M	3.20E-02	1.006	FAILURE TO MANUALLY DEPRESSURIZE THE RPV WITHIN 10 MIN.	This event appears in cutsets related to ATWS scenarios. No cost-beneficial SAMA was feasible based on low probability of mechanical scram failure. (No specific SAMA identified).
SWS-STR-FR-DF01	2.78E-06	1.006	CCF FAILURE TO RUN ALL SWS STRNR MOTORS	This event is associated with those cutsets that can be mitigated via SAMAs 4, 5 and 15.
%FLFPS-RBU	6.60E-05	1.006	FPS RUPTURE IN RB UPPER LEVELS	SAMA 8 applies to this event.
FPS-XHE-RB-E	1.00E+00	1.006	FAILURE TO ISOLATE FPS PIPE RUPTURE IN THE REACTOR BUILDING (EARLY)	SAMA 8 applies to this event.
SWS-MOV-VF-SPRAY	1.00E-01	1.006	Flood - SPRAY CAUSES MOV FAILURE IN RACS COMPARTMENT	This is associated with a low probability scenario that conservatively assumes failure of MOVs due to spray damage; there is no feasible SAMA identified for this type of event.
LPI-XHE-AT-LVL	4.00E-02	1.006	FAILURE TO CONTROL LP ECCS TO PREVENT OVERFILL	This event appears in cutsets related to ATWS scenarios. No cost-beneficial SAMA was feasible based on low probability of mechanical scram failure. (No specific SAMA identified).

TABLE E.5-1
LEVEL 1 IMPORTANCE LIST REVIEW

EVENT NAME	PROBABILITY	RISK REDUCTION WORTH	DESCRIPTION	POTENTIAL SAMAS
SWS-PHE-PMP-HD	9.00E-01	1.006	SW HEAD INADEQUATE	This event appears in conjunction with RHS-REPAIR, which is addressed by SAMA 4.

TABLE E.5-2
LEVEL 2 IMPORTANCE LIST REVIEW

EVENT NAME	PROBABILITY	RISK REDUCTION WORTH	DESCRIPTION	POTENTIAL SAMAS
CGS-PHE-FF-INERT	9.90E-01	7.759	CONTAINMENT INERTED; VENTING NOT REQUIRED	Indication of plant configuration / condition. (No specific SAMA identified)
CNT-MDL-FF-SCTRM	1.00E+00	2.484	REACTOR BUILDING INEFFECTIVE IN REDUCING SOURCE TERM	This event assumes no credit for source term scrubbing. There was no feasible SAMA identified for this event.
RX-NOCREDIT	1.00E+00	2.439	FAILURE OF IN-VESSEL RECOVERY	This event assumes no credit for in-vessel recovery. There was no feasible SAMA identified for this event.
CNT-MDL-FF-LVL1F	1.00E+00	1.747	LG CONT. FAILURE GIVEN CONT. FAILED IN LEVEL 1 (CLASS II, IIID, IV)	This is conditional probability based on plant damage state. (No specific SAMA identified)
CNT-DWV-FF-MLTFL	1.00E+00	1.731	DW SHELL MELT-THROUGH FAILURE DUE TO CONT. FAILURE	This event assumes immediate failure of containment due to core melt-through, which implies that as soon as molten corium contacts the DW inner liner, containment failure is guaranteed. There was no feasible SAMA identified for this event.
DIA	9.78E-01	1.518	DRYWELL FAILURE (CLASS IIA)	This is a split fraction used in the CET for condition of DW. (No specific SAMA identified)
OP6-IIA-NOT	8.80E-01	1.427	0	This is a split fraction for success path in CET. (No specific SAMA identified)
RHR-MCU-FF-MSIVS	1.00E+00	1.279	PCS UNAVAILABLE AS HEAT SINK	This event appears in combination with RHS-REPAIR-TR. See SAMA 4 (L1 List).

TABLE E.5-2
LEVEL 2 IMPORTANCE LIST REVIEW

EVENT NAME	PROBABILITY	RISK REDUCTION WORTH	DESCRIPTION	POTENTIAL SAMAS
RHR-MDL-FF-EOPCM	1.00E+00	1.279	CONTINGENCY METHODS INADEQUATE (NOT CREDITED)	This is a place holder event for contingency methods that are not credited in the PRA model. See SAMA 4 (L1 List).
1RXPH-CRDINJ-F--	1.00E+00	1.264	CRD INJECTION INADEQUATE	This is a flag event representing the inability to inject water into the vessel. SAMA 1 (L1 List) would provide some benefit.
1RXPH-HPCIRVLF--	1.00E+00	1.264	HPCI UNAVAILABLE	This is a flag event representing the inability to inject water into the vessel. SAMA 1 (L1 List) would provide some benefit.
1RXPH-MNFDWTRF--	1.00E+00	1.264	MAIN FEEDWATER SYSTEM UNAVAILABLE	This is a flag event representing the inability to inject water into the vessel. SAMA 1 (L1 List) would provide some benefit.
1RXPH-RCICINAF--	1.00E+00	1.264	RCIC SYSTEM INADEQUATE	This is a flag event representing the inability to inject water into the vessel. SAMA 1 (L1 List) would provide some benefit.
VF--XHE-L2-INREC	9.00E-01	1.264	OPERATOR FAIL TO RECOVER INJECTION BEFORE RPV BREACH	This event is also associated with flooding scenarios previously identified in the L1 list. SAMAs 7 and 8 (L1 List) will provide some benefit.
IS1-IA-NOT	8.00E-01	1.238	0	This is a split fraction for success path in CET. (No specific SAMA identified)
CNT-MDL-SC-MDTMP	1.00E+00	1.143	SM CONT. FAILURE AT INTER DW TEMP. (CLASS I, III WITH RPV BREACH)	This is a flag event tied to a type of accident sequence. (No specific SAMA identified)
FC5-3B-NOT	5.90E-01	1.125	CONTAINMENT FLOODING INITIATED (IIIB)	This is a split fraction for success path in CET. (No specific SAMA identified)

TABLE E.5-2
LEVEL 2 IMPORTANCE LIST REVIEW

EVENT NAME	PROBABILITY	RISK REDUCTION WORTH	DESCRIPTION	POTENTIAL SAMAS
1RXRX-ONEACL-F--	1.00E+00	1.111	ONSITE EMERGENCY AC POWER NOT RECOVERED	See SAMA 5 (L1 list)
OP5-NOT	8.80E-01	1.109	0	This is a split fraction for success path in CET. (No specific SAMA identified)
1RXRX-OFFACL-F--	6.00E-01	1.109	OFFSITE AC POWER NOT RECOVERED	See SAMA 5 (L1 list)
OP--XHE-ALT-DEP	1.00E+00	1.099	ALTERNATE DEPRESS. METHODS NOT CREDITED	See SAMA 4 (L1 List)
UV1-XHE-ALDHR-RX	1.00E+00	1.099	Op. Fails to Align Alternate Inj. Flow Paths to Recover In-Vessel Core Damage	This event appears in combination with RHS-REPAIR-L which was identified in the L1 SAMA List. See SAMA 4 (L1 List).
1OPPH-PRESBK-F--	8.00E-01	1.099	PRESSURE TRANSIENT DOES NOT FAIL MECHANICAL SYSTEMS	This is a split fraction for success path in CET. (No specific SAMA identified)
1OPPH-TEMPBK-F--	7.00E-01	1.099	HIGH PRIM SYS TEMP DOES NOT CAUSE FAIL OF RCS PRESS. BOUND	This is a split fraction for success path in CET. (No specific SAMA identified)
1OPPH-SORV---F--	5.50E-01	1.099	SRVs DO NOT FAIL OPEN DURING CORE MELT PROGRESSION	This is a split fraction for success path in CET. (No specific SAMA identified)
CMS-MDL-SC-LFLMT	1.00E+00	1.098	LG. CONT. FAILURE DOES NOT COMPROMISE M/U SOURCES (INTERMED. TEMP)	This is a flag event tied to other Level 2 plant phenomena. (No specific SAMA identified)
CMS-MDL-SC-MDTMP	5.00E-01	1.087	CONT. LEAK. OR VENT DOES NOT COMPROMISE M/U SOURCES (INTERMED. TEMP)	This is a flag event tied to other Level 2 plant phenomena. (No specific SAMA identified)

TABLE E.5-2
LEVEL 2 IMPORTANCE LIST REVIEW

EVENT NAME	PROBABILITY	RISK REDUCTION WORTH	DESCRIPTION	POTENTIAL SAMAS
CGS-XHE-L2-VENT	2.51E-01	1.086	OPERATOR FAILS TO VENT (HC.OP.EO-ZZ.0318)	This event appears in combination with RHS-REPAIR-L which was identified in the L1 SAMA List. See SAMA 4 (L1 List).
VC1-ID-NOT	6.70E-01	1.075	0	This is a split fraction for success path in CET. (No specific SAMA identified)
1RX-PHE-SUBSUME	1.00E+00	1.072	ACCIDENT TIME DOES NOT EXCEED 4 HRS TO CORE DAMAGE	This is a flag event tied to other Level 2 plant phenomena. (No specific SAMA identified)
DIATWS-NOT	9.90E-01	1.062	DW INTACT ATWS	This is a split fraction for success path in CET. (No specific SAMA identified)
CND-SYS-FF-LERF	1.00E+00	1.055	0	This is a flag event tied to other Level 2 plant phenomena. (No specific SAMA identified)
OP6-NOT	9.00E-01	1.055	0	This is a split fraction for success path in CET. (No specific SAMA identified)
SWS-XHE-RACS-UNI	1.00E+00	1.051	FAILURE TO ISOLATE LOCALLY A SW RUPTURE IN RACS COMPARTMENT	See SAMA 7 (L1 List)
1OPPH-CNTFAD-F--	4.50E-01	1.051	STRUCTURAL BREACH IN CONT. CUASES FAILURE OF ADS	This is a conditional probability based on structural failure of containment. No feasible method of reinforcing ADS supply to preclude this event. (No specific SAMA identified)
FPS-XHE-CRISOL	1.00E+00	1.047	Operator fails to secure FPS given CR area rupture	See SAMA 8 (L1 List)
MCR-PHE-DOOR	5.00E-01	1.047	MCR DOOR FAILS DUE TO WATER PRESSURE	See SAMA 8 (L1 List)

TABLE E.5-2
LEVEL 2 IMPORTANCE LIST REVIEW

EVENT NAME	PROBABILITY	RISK REDUCTION WORTH	DESCRIPTION	POTENTIAL SAMAS
PCV-XHE-L2-VENT	1.30E-01	1.047	OPERATOR FAILS TO VENT (HC.OP-EO-ZZ.0318)	This event appears in combination with RHS-REPAIR-L which was identified in the L1 SAMA List. See SAMA 4 (L1 List).
%FLFPS-CR	1.10E-05	1.047	FPS RUPTURE OUTSIDE CONTROL ROOM	See SAMA 8 (L1 List)
L2-OSP-24H-SW	8.57E-01	1.043	COND PROB OF FAILURE TO RESTORE AC IN L2 W/IN 24 HRS. NODE SI	Same as SAMA 5 (L1 list)
CIS-DRAN-L2-OPEN	1.00E+00	1.038	VALVES OPEN AUTOMATICALLY FOR DRAINAGE NORMALLY OPEN	The major contributor is loss of power to these valves. SAMA 5 (L1 List) will provide benefit. Another means to address this, although more costly, is to replace the MOVs with FC AOVs.
SWS-PHE-PMP-HD	9.00E-01	1.037	SW HEAD INADEQUATE	See SAMA 4 (L1 list)
PCS-SYS-RP-DWFAIL	4.30E-01	1.037	LARGE DW CONTAINMENT FAILURE CAUSES LOSS OF INJECTION	This is a conditional probability based on structural failure of containment. No feasible method of reinforcing injection piping to preclude this event. (No specific SAMA identified)
RHS-MDP-TM-PB	1.58E-02	1.035	RHS PUMP TRAIN B IN TEST AND MAINT	See SAMAs 1, 4 and 8 (L1 List)
WWATWS	5.00E-01	1.03	WW FAILURE ATWS	L2 phenomenology probability. (No specific SAMA identified)
WWATWS-NOT	5.00E-01	1.03	WW FAILURE ATWS	This is a split fraction for success path in CET. (No specific SAMA identified)

TABLE E.5-2
LEVEL 2 IMPORTANCE LIST REVIEW

EVENT NAME	PROBABILITY	RISK REDUCTION WORTH	DESCRIPTION	POTENTIAL SAMAS
L2-OSP-11H-SW	7.46E-01	1.025	COND. PROB. OF FAILURE TO RESTORE AC IN L2 W/IN 11 HRS IN NODE SI	See SAMA 5 (L1 List)
1RXRX-ONEACE-F--	1.00E+00	1.023	ONSITE EMERGENCY AC POWER NOT RECOVERED	See SAMA 5 (L1 list)
1RXRX-OFFACE-F--	6.30E-01	1.023	OFFSITE AC POWER NOT RECOVERED	See SAMA 5 (L1 list)
DIT	1.00E+00	1.022	DRYWELL FAILURE (CLASS IIT AND IIID)	This is a flag event tied to a type of accident sequence. (No specific SAMA identified)
CGS-PHE-FF-STMIN	9.90E-01	1.022	COMBUSTIBILE GAS VENTING NOT REQUIRED (STEAM INERTED - CLASS IIID)	L2 phenomenology probability. (No specific SAMA identified)
L2-OSP-8H-SW	6.75E-01	1.022	COND. PROB. OF FAILURE TO RESTORE AC IN L2 W/IN 8 HRS IN NODE SI	See SAMA 5 (L1 List)
CIS-XHE-FO-DRN-E	1.00E+00	1.021	OP FAILS TO LOCALLY CLOSE EQ. DRN AND FLR DRN MOV IN RB-EARLY	The major contributor is loss of power to these valves. SAMA 5 (L1 List) will provide benefit. Another means to address this, although more costly, is to replace the MOVs with FC AOVs.
ACP-XHE-L2-OP	5.00E-01	1.021	OPERATOR FAILS TO RESTORE AC POWER DURING BOIL-OFF	See SAMA 5 (L1 List)
CSS-STR-PL-A	8.36E-03	1.021	CSS PUMP A SUCTION STRAINERS PLUGGED IN STANDBY	See SAMA 15 (L1 List)

TABLE E.5-2
LEVEL 2 IMPORTANCE LIST REVIEW

EVENT NAME	PROBABILITY	RISK REDUCTION WORTH	DESCRIPTION	POTENTIAL SAMAS
CSS-STR-PL-B	8.36E-03	1.021	CSS PUMP B SUCTION STRAINERS PLUGGED IN STANDBY	See SAMA 15 (L1 List)
CSS-STR-PL-C	8.36E-03	1.021	CSS PUMP C SUCTION STRAINERS PLUGGED IN STANDBY	See SAMA 15 (L1 List)
CSS-STR-PL-D	8.36E-03	1.021	CSS PUMP D SUCTION STRAINERS PLUGGED IN STANDBY	See SAMA 15 (L1 List)
DCP-BDC-ST-DF01	3.87E-08	1.021	CCF FAILURE 125VDC BUSES 10D410 - 20 - 30 - & 40	Based on low contribution to L1 and L2 and engineering judgment, the anticipated implementation cost of hardware mods associated with mitigating this event would likely exceed the expected cost-risk benefit. (No specific SAMA identified)
NR-CSC-VSS-INIT	3.90E-02	1.02	OPERATOR FAILS TO INITIATE DRYWELL SPRAYS	Although this HEP was analyzed in detail and operator training and procedures were deemed adequate, the relatively high failure rate was attributed to short time available to perform action. Further training and/or procedure enhancement will not reduce the failure probability. However, this event appears in conjunction with XHE-OK-INHIB and therefore SAMA 1 (L1 List) would apply.

TABLE E.5-2
LEVEL 2 IMPORTANCE LIST REVIEW

EVENT NAME	PROBABILITY	RISK REDUCTION WORTH	DESCRIPTION	POTENTIAL SAMAS
%FLSWAB-RACS-U	7.60E-08	1.02	FREQ OF COMMON HEADER TO RACS RUPTURE (UNISOLABLE)	Based on low contribution to L1 risk and engineering judgment, the anticipated implementation cost of hardware mods associated with mitigating this event would likely exceed the expected cost-risk benefit. (No specific SAMA identified)
CAC-LOG-NO-AC652	3.33E-03	1.019	LOGIC CIRCUIT AT AC652 FAILS.	See SAMA 4 (L1 list)Given the low RRW value of <1.02, this modification may not be cost beneficial if implementation costs are greater than $500K.
CAC-LOG-NO-DC652	3.33E-03	1.019	LOGIC CIRCUIT TO HV-4978 FAILS.	See SAMA 4 (L1 list) Given the low RRW value of <1.02, this modification may not be cost beneficial if implementation costs are greater than $500K.
OP1-IA-NOT	8.40E-01	1.018	RPV DEPRESSURIZATION SUCCESSFUL (IA)	This is a split fraction for success path in CET. (No specific SAMA identified)
CIS-XHE-FO-DRN-L	1.30E-01	1.018	OP FAILS TO LOCALLY CLOSE EQ. DRN AND FLR DRN MOV IN RB-LATE	See SAMA 5 (L1 List) Given the low RRW value of <1.02, this modification may not be cost beneficial if implementation costs are greater than $500K.
NRHVCSWGR24-01	4.10E-03	1.017	Fail to restore SWGR room cooling	SAMA 16 (L1 List) will provide some benefit since this event appears most of the time with common cause failure of the room cooling fans. Given the low RRW value of <1.02, this modification may not be cost beneficial if implementation costs are greater than $500K.

TABLE E.5-2
LEVEL 2 IMPORTANCE LIST REVIEW

EVENT NAME	PROBABILITY	RISK REDUCTION WORTH	DESCRIPTION	POTENTIAL SAMAS
SLC-XHE-L-LVLCND	3.91E-02	1.016	LATE RPV WATER LEVEL CONTROL (CONDITIONAL)	This is a conditional probability based on sequence of events related to ATWS. No cost-beneficial SAMA was feasible based on low probability of mechanical scram failure. (No specific SAMA identified) Given the low RRW value of <1.02, this modification may not be cost beneficial if implementation costs are greater than $500K.
L2-OSP-10H-SW	7.26E-01	1.015	COND PROB OF FAILURE TO RESTORE AC IN L2 W/IN 10 HRS IN NODE SI	See SAMA 5 (L1 list) Given the low RRW value of <1.02, this modification may not be cost beneficial if implementation costs are greater than $500K.
OSP65HR-SW	3.07E-01	1.015	FAILURE TO RECOVER OSP WITHIN 6 HOURS (SEVERE WEATHER LOOP EVENT)	See SAMA 5 (L1 list)Given the low RRW value of <1.02, this modification may not be cost beneficial if implementation costs are greater than $500K.
DCP-EDG-PORTGEN	2.50E-02	1.015	PORTABLE GENERATOR FAILS	See SAMA 5 (L1 list) Given the low RRW value of <1.02, this modification may not be cost beneficial if implementation costs are greater than $500K.
CSS-MDP-TM-PAC	1.36E-02	1.015	CSS PUMP TRAINS A AND C IN TEST AND MAINT	Based on low contribution to L1 risk and engineering judgment, the anticipated implementation cost of hardware mods associated with mitigating this event would likely exceed the expected cost-risk benefit. (No specific SAMA identified)

TABLE E.5-2
LEVEL 2 IMPORTANCE LIST REVIEW

EVENT NAME	PROBABILITY	RISK REDUCTION WORTH	DESCRIPTION	POTENTIAL SAMAS
CSS-MDP-TM-PBD	1.36E-02	1.015	CSS PUMP TRAINS B AND D IN TEST AND MAINT	Based on low contribution to L1 risk and engineering judgment, the anticipated implementation cost of hardware mods associated with mitigating this event would likely exceed the expected cost-risk benefit. (No specific SAMA identified)
%FLSWA-RACS-U	5.70E-08	1.015	FREQ. OF UNISOLABLE SW A PIPE RUPT IN RACS ROOM	Based on low contribution to L1 risk and engineering judgment, the anticipated implementation cost of hardware mods associated with mitigating this event would likely exceed the expected cost-risk benefit. (No specific SAMA identified)
%FLSWB-RACS-U	5.70E-08	1.015	FREQ. OF UNISOLABLE SW B PIPE RUPT. IN RACS ROOM	Based on low contribution to L1 risk and engineering judgment, the anticipated implementation cost of hardware mods associated with mitigating this event would likely exceed the expected cost-risk benefit. (No specific SAMA identified)
RHR-XHE-RHR-INJ	1.00E-01	1.014	FAILURE TO ALIGN RHR MOV 17B LOCALLY FOR INJECTION	See SAMA 10 (L1 List) Given the low RRW value of <1.02, this modification may not be cost beneficial if implementation costs are greater than $500K.
CAC-AOV-CC-DF01	2.00E-04	1.014	COMMON CAUSE FAILURE OF AIR OPERATED BUTTERFLY VALVES TO OPEN	See SAMA 4 (L1 list)Given the low RRW value of <1.02, this modification may not be cost beneficial if implementation costs are greater than $500K.

TABLE E.5-2
LEVEL 2 IMPORTANCE LIST REVIEW

EVENT NAME	PROBABILITY	RISK REDUCTION WORTH	DESCRIPTION	POTENTIAL SAMAS
SAC-MDP-TM-SSWA	2.30E-05	1.014	SAC-B IN MAINT. COINCIDENT WITH SSW A	This is a low probability event that is not part of routine maintenance. This type of situation is monitored via the online maintenance (a4) process. (No specific SAMA identified)
ACP-BAC-HV-RMCLG	9.00E-01	1.013	FAILURE OF EQUIPMENT GIVEN NO SWG ROOM COOLING	See SAMA 16 (L1 List) Given the low RRW value of <1.02, this modification may not be cost beneficial if implementation costs are greater than $500K.
FC1-IA-NOT	2.80E-01	1.013	0	This is a split fraction for success path in CET. (No specific SAMA identified)
ESF-XHE-MC-DF01	8.00E-05	1.013	COMMON CAUSE MISCALIBRATION OF ALL ECCS PRESSURE TRANS.	This is a low probability event. Further training and/or procedure enhancement will not reduce the failure probability. (No specific SAMA identified)
ESF-XHE-MC-DF01	8.00E-05	1.013	COMMON CAUSE MISCALIBRATION OF ALL ECCS PRESSURE TRANS.	This is a low probability event. Further training and/or procedure enhancement will not reduce the failure probability. (No specific SAMA identified)
DGS-DGN-TM-ABCD	2.30E-05	1.013	COINCIDENT MAINTENANCE UNAVAILABILITY OF DG A, DG B, DG C, AND DG D	This is a low probability event that is not part of routine maintenance. This type of situation is monitored via the online maintenance (a4) process. (No specific SAMA identified)
VSW-FAN-FR-DF12	9.90E-06	1.013	CCF FAILURE FANS A THRU DVH401 FAIL TO RUN	See SAMA 16 (L1 List) Given the low RRW value of <1.02, this modification may not be cost beneficial if implementation costs are greater than $500K.

TABLE E.5-2
LEVEL 2 IMPORTANCE LIST REVIEW

EVENT NAME	PROBABILITY	RISK REDUCTION WORTH	DESCRIPTION	POTENTIAL SAMAS
IE-LOOP-CND-L	2.40E-02	1.012	CONDITIONAL LOOP GIVEN TRANSIENT WITH LOCA SIGNAL	See SAMA 3 and 5 (L1 List) Given the low RRW value of <1.02, this modification may not be cost beneficial if implementation costs are greater than $500K.
HPI-STR-PL-DFLOC	1.00E-04	1.012	CCF PLUGGING OF ECCS SUCTION STRAINERS (LOCA)	This event is addressed by various NRC documents (GSI-191, others) for all nuclear sites, and therefore, no further work is deemed necessary. (No specific SAMA identified)
VC1-IA-NOT	8.00E-01	1.01	0	This is a split fraction for success path in CET. (No specific SAMA identified)
VC1-IBL-NOT	7.50E-01	1.01	0	This is a split fraction for success path in CET. (No specific SAMA identified)
XHOS-STBY-DP502LT	5.00E-01	1.01	PUMP SSW DP502 IN STANDBY WITH 2 PUMPS OPERATING	This event represents the normal configuration of SSW pumps. Specific SAMAs associated with this system are addressed elsewhere. (No specific SAMA identified)
CMS-MDL-SC-LOOPL	5.00E-01	1.01	CONT. LEAK OR VNT DOES NOT COMPROMISE MU SOURCES (INTER. TMP)	This is a flag event tied to other Level 2 plant phenomena. (No specific SAMA identified)
FPS-XHE-ALIGN	5.80E-02	1.01	FAILURE TO ALIGN FPS FOR INJECTION IN TIME	This HEP was analyzed in detail. Operator training and procedures were deemed adequate. Relatively high failure rate attributed to short time available to perform action. Further training and/or procedure enhancement will not reduce the failure probability. (No specific SAMA identified)

TABLE E.5-2
LEVEL 2 IMPORTANCE LIST REVIEW

EVENT NAME	PROBABILITY	RISK REDUCTION WORTH	DESCRIPTION	POTENTIAL SAMAS
LPI-XHE-AT-LVL	4.00E-02	1.01	FAILURE TO CONTROL LP ECCS TO PREVENT OVERFILL	This HEP was analyzed in detail. Operator training and procedures were deemed adequate. Relatively high failure rate attributed to short time available to perform action. Further training and/or procedure enhancement will not reduce the failure probability. (No specific SAMA identified)
DGS-DGN-FS-BG400	1.31E-02	1.01	DIVISION B DIESEL 1BG400 FAILS TO START	See SAMA 5 (L1 List) Given the low RRW value of <1.02, this modification may not be cost beneficial if implementation costs are greater than $500K.
HPI-TDP-TM-OP204	1.09E-02	1.01	HPI TURBINE TRAIN OP204 IN TEST AND MAINT	See SAMA 1 (L1 List) Given the low RRW value of <1.02, this modification may not be cost beneficial if implementation costs are greater than $500K.
%IE-TF	4.49E-02	1.009	LOSS OF FEEDWATER	This initiating event is tied to plant-specific operating experience. (No specific SAMA identified).
CGS-PHE-SC-INERT	1.00E-02	1.009	CONTAINMENT NOT INERTED; VENTING REQUIRED	This is a plant condition not related to any specific failure; this event appears in those cutsets addressed by SAMAs 1, 4, and 8.
WW-DW-LK-RUPT	1.00E-01	1.009	RB SYS FAIL DUE TO ENVRON. STRESS WW RUPT/LK	This event appears in conjunction with RHS-REPAIR, which is addressed by SAMA 5.
OSPR30MIN-GR	8.25E-01	1.009	FAILURE TO RECOVER GRID LOOP W/IN 30 MIN.	SAMA 5 applies to this event.
RHS-STR-PL-PB	4.21E-03	1.009	RHR SUCTION STRAINER B PLUGGED IN STANDBY	SAMA 4 applies to this event.

TABLE E.5-2
LEVEL 2 IMPORTANCE LIST REVIEW

EVENT NAME	PROBABILITY	RISK REDUCTION WORTH	DESCRIPTION	POTENTIAL SAMAS
RCI-MOV-LK-ROOM	1.00E-01	1.009	PROBABILITY OF STEAM LEAK INTO RCI ROOM	This event appears with LOOP sequences; addressed by SAMA 5.
%IE-SORV2	2.44E-04	1.009	2 or More SORVs	SAMA 1 applies to this event.
IAS-MDC-FR-K100	6.09E-02	1.009	EIA COMPRESSOR FAILS TO RUN	SAMA 3 applies to this event.
NR-ATWS-ADS-INH	1.50E-02	1.008	FAILURE TO INHIBIT ADS DURING AN ATWS (W/O FW)	This event appears in cutsets related to ATWS scenarios. No cost-beneficial SAMA was feasible based on low probability of mechanical scram failure. (No specific SAMA identified).
1CZPH-EXVSLSTF--	1.00E-02	1.008	EX-VESSEL STEAM EXPLOSION	Even though this is an event related to L2 phenemonology, SAMAs 1, 4, and 8 will provide some benefit.
%FL-FPS-5302	6.62E-06	1.008	INT. FLOOD OUTSIDE LOWER RELAY ROOM	This event was addressed in the L1 importance list.
FPS-XHE-5302IS	5.00E-01	1.008	OP. FAILS TO SECURE FPS GIVEN LCER AREA RUPTURE (EARLY)	This event was addressed in the L1 importance list.
LCER-PHE-DOOR	1.00E+00	1.008	LCER DOOR FAILS DUE TO WATER PRESSURE	This event was addressed in the L1 importance list.
DGS-DGN-FS-DG400	1.31E-02	1.008	DIVISION D DIESEL 1DG400 FAILS TO START	This event was addressed in the L1 importance list.
RSP-XHE-CBFLD	4.00E-03	1.007	FAILURE TO CNTRL PLANT USING REMOTE SHTDWN PANEL FLLWNG FPS RUPTURE OUTSIDE LWR	SAMA 8 applies to this event.

TABLE E.5-2
LEVEL 2 IMPORTANCE LIST REVIEW

EVENT NAME	PROBABILITY	RISK REDUCTION WORTH	DESCRIPTION	POTENTIAL SAMAS
CSS-MDP-TM-PA	7.51E-03	1.007	CSS PUMP TRAIN A IN TEST AND MAINT	This event was addressed in the L1 importance list.
CSS-MDP-TM-PB	7.51E-03	1.007	CSS PUMP TRAIN B IN TEST AND MAINT	Similar event that was previously addressed in L1 importance list.
CSS-MDP-TM-PC	7.51E-03	1.007	CSS PUMP TRAIN C IN TEST AND MAINT	This event was addressed in the L1 importance list.
CSS-MDP-TM-PD	7.51E-03	1.007	CSS PUMP TRAIN D IN TEST AND MAINT	Similar event that was previously addressed in L1 importance list.
LPI-XHE-AT-LVLF	1.00E-01	1.007	FAILURE TO CNTRL LP ECCS TO PRVNT OVERFILL GIVEN HPI FAILS	This event appears in cutsets related to ATWS scenarios. No cost-beneficial SAMA was feasible based on low probability of mechanical scram failure. (No specific SAMA identified).
SLC-TNK-LO-10204	7.55E-03	1.006	SLC STORAGE TANK CONCENTRATION OUT OF SPEC.	This event appears in cutsets related to ATWS scenarios. No cost-beneficial SAMA was feasible based on low probability of mechanical scram failure. (No specific SAMA identified).
LOOP-IE-SWYD	4.03E-01	1.006	COND. PROBABILITY LOOP DUE TO SWYD EVENT	This event was addressed in the L1 importance list.
%FLTORUS	2.80E-06	1.006	TORUS RUPTURE IN TORUS ROOM	This is a low probability event with no feasible cost-beneficial SAMA identified; SAMA 1 may provide some benefit.
DGS-DGN-FS-AG400	1.31E-02	1.006	DIVISION A DIESEL 1AG400 FAILS TO START	SAMA 5 applies to this event.

TABLE E.5-2
LEVEL 2 IMPORTANCE LIST REVIEW

EVENT NAME	PROBABILITY	RISK REDUCTION WORTH	DESCRIPTION	POTENTIAL SAMAS
SRV-TNK-LK-TRANS	1.00E-04	1.006	FAILURE OF 13/14 ACCUMULATORS (LEAKAGE) (NON-SBO)	This event was addressed in the L1 importance list.
SWS-STR-FR-DF01	2.78E-06	1.006	CCF FAILURE TO RUN ALL SWS STRNR MOTORS	This event is associated with those cutsets that can be mitigated via SAMAs 4, 5 and 15.
HPI-XHE-AT-CS	1.10E-01	1.006	CREW BLOWS DOWN BEFORE LVL IS CONTROLLED BY HPCI (3600 GPM)	This event appears in cutsets related to ATWS scenarios. No cost-beneficial SAMA was feasible based on low probability of mechanical scram failure. (No specific SAMA identified).
DGS-DGN-TM-BG400	1.30E-02	1.006	DGS TRAIN BG400 IN TEST AND MAINT	This event was addressed in the L1 importance list.
SAC-MDP-TM-SSWB	2.30E-05	1.006	SAC A IN MAINT. COINCIDENT WITH SSW B	SAMA 3 applies to this event.
DIA-NOT	2.20E-02	1.006	DRYWELL INTACT (CLASS IIA)	This is a split fraction for success path in CET. (No specific SAMA identified).
WWA	1.00E+00	1.006	WETWELL AIRSPACE FAILURES (CLASS IIA)	SAMA 4 applies to this event.

TABLE E.5-3
HCGS PHASE 1 SAMA LIST SUMMARY

SAMA NUMBER	SAMA TITLE	SAMA DESCRIPTION	SOURCE	COST ESTIMATE (1)	RETAINED	PHASE 1 BASELINE DISPOSITION
1	Remove ADS inhibit from non-ATWS emergency operating procedures	Investigate the design basis for inhibiting ADS. If ADS does not have to be inhibited except for ATWS, it can be credited for reducing pressure in more scenarios. Susquehanna and LaSalle have taken this approach. An alternative solution is to install an injection system capable of operating at high pressures. However, this solution is a much costlier option and may likely prove not be a practical approach to mitigating this event.	HCGS Level 1 Importance List	$200,000	Yes	See Section E.6.1
3	Install Back-Up air compressor to Supply AOVs	Provide a back-up air compressor to supply AOVs with an alternate air source.	HCGS Level 1 Importance List	$700,000	Yes	See Section E.6.2
4	Provide procedural guidance to cross-tie RHR trains	Provide the ability to cross-tie RHR pumps trains. Although the piping network exists, it is not allowed by procedure.	HCGS Level 1 Importance List	$100,000	Yes	See Section E.6.3
5	Restore AC power with onsite gas turbine generator	Improve procedural use of gas turbine generator to restore onsite emergency AC power sources.	HCGS Level 1 Importance List	$2,050,000	Yes	See Section E.6.4

TABLE E.5-3
HCGS PHASE 1 SAMA LIST SUMMARY

SAMA NUMBER	SAMA TITLE	SAMA DESCRIPTION	SOURCE	COST ESTIMATE [1]	RETAINED	PHASE 1 BASELINE DISPOSITION
7	Install better flood detection instrumentation for RACS compartment	This HRE represents an internal flooding scenario that disables various safety-related components. Mitigation of this event can be accomplished by replacing manual isolation valves with remotely-operated MOVs with automatic isolation capability.	HCGS Level 1 Importance List	$3,070,000	Yes	See Section E.6.5
8	Convert selected fire protection piping from wet pipe to dry pipe system	This HRE represents an internal flooding scenario that disables various safety-related components. Mitigation of this event can be accomplished by changing the existing FPS to a dry-pipe system. Limerick took this approach.	HCGS Level 1 Importance List	$600,000	Yes	See Section E.6.6
10	Provide procedural guidance to use B.5.b low pressure pump for non-security events	Since this involves loss of long-term RHR, provide an independent means of alternate makeup to RPV. Possible suction sources are CST, RST and FPS. Possible use of an alternate diesel-driven pump combined with rapid depressurization.	HCGS Level 1 Importance List	$100,000	Yes	See Section E.6.7
14	Alternate room cooling for SW rooms	Provide an alternate means of opening the Torus Vent valves when remote operation fails. Adequate time is available given this is a long term sequence.	HCGS Level 1 Importance List	$500,000	No	SAMA 14 has been subsumed into SAMA 4 (Cross-tie RHR pump trains).

TABLE E.5-3
HCGS PHASE 1 SAMA LIST SUMMARY

SAMA NUMBER	SAMA TITLE	SAMA DESCRIPTION	SOURCE	COST ESTIMATE (1)	RETAINED	PHASE 1 BASELINE DISPOSITION
15	Alternate design of CSS suction strainer to mitigate plugging	Consider alternate design of CSS suction strainer to mitigate plugging.	HCGS Level 1 Importance List	$1,000,000	Yes	See Section E.6.8
16	Use of different designs for switchgear room cooling fans	Consider replacing one of the SWGR room cooling fans with a different design so as to eliminate common cause failure of all fans.	HCGS Level 1 Importance List	$400,000	Yes	See Section E.6.9
17	Replace a supply fan with a different design in service water pump room	Consider replacing one of the SW pump room supply fans with a different design so as to eliminate common cause failure of all fans.	HCGS Level 1 Importance List	$600,000	Yes	See Section E.6.10
18	Replace a return fan with a different design in service water pump room	Consider replacing one of the SW pump room return fans with a different design so as to eliminate common cause failure of all fans.	PRA Group Insight	$600,000	Yes	See Section E.6.11
30	Provide procedural guidance for partial transfer of control functions from the control room to the remote shutdown panel	For fires that cause catastrophic damage to the controls of a single critical system, the reliability of controling the plant may be improved by allowing the operators to transfer only a single division of controls to the RSP to recover a channel of the critical system while the MCR is maintained as the primary control center. A permutaiton of this SAMA would be to use local system controls rather than the RSP.	IPEEE (Fire)	$100,000	Yes	See Section E.6.12

TABLE E.5-3
HCGS PHASE 1 SAMA LIST SUMMARY

SAMA NUMBER	SAMA TITLE	SAMA DESCRIPTION	SOURCE	COST ESTIMATE [1]	RETAINED	PHASE 1 BASELINE DISPOSITION
31	Install improved fire barriers in the MCR control cabinets containing the primary MSIV control circuits	MCR fires that propagate from the originating cabinets result in widespread control damage and induce environmental conditions that would require abandonment even if the controls were not damaged. IPEEE insights suggest that improving the fire barriers in the console containg the primary MSIV controls would reduce the probability of these types of fire events.	IPEEE (Fire)	$1,200,000	Yes	See Section E.6.13
32	Install additional physical barriers to limit dispersion of fuel oil from DG rooms	For compartment 5339 fire scenario 5339_2, install a curb or a diversion channel to ensure liquids from the DG rooms cannot communicate with Room 5339.	IPEEE (Fire)	$800,000	Yes	See Section E.6.14
33	Install Division II 480VAC bus cross-ties	For DG room (D) fire scenario 5304_2, install cross-ties between the Division II 480VAC buses (potentially 10B420 to10B480 and 10B460 to 10B440).	IPEEE (Fire)	$1,320,000	Yes	See Section E.6.15
34	Install Division I 480VAC bus cross-ties	For DG room (C) fire scenario 5306_2, install cross-ties between the Division I 480VAC buses (potentially 10B410 to10B430 and 10B450 to 10B470).	IPEEE (Fire)	$1,320,000	Yes	See Section E.6.16

TABLE E.5-3
HCGS PHASE 1 SAMA LIST SUMMARY

SAMA NUMBER	SAMA TITLE	SAMA DESCRIPTION	SOURCE	COST ESTIMATE [1]	RETAINED	PHASE 1 BASELINE DISPOSITION
35	Relocate, minimize, and/or eliminate electrical heaters in electrical access room	For compartment 3425/5401 fire scenario 5401_1, move or eliminate the electrical heaters in the electrical access room (Aux Building 124' level) to prevent damage to the Division II power cables.	IPEEE (Fire)	$270,000	Yes	See Section E.6.17
36	Provide procedural guidance for loss of all 1E 120V AC power	For Seismic-Induced Equipment Damage State SET-36 (Impacts - 120V PNL481), develop MCR procedures to operate the plant after a loss of all class 1E 120V AC power.	IPEEE (Seismic)	$270,000	Yes	See Section E.6.18
37	Reinforce 1E 120V AC distribution panels	For Seismic-Induced Equipment Damage State SET-36 (Impacts - 120V PNL481), reinforce the class 1E 120V AC distribution panels.	IPEEE (Seismic)	$500,000	Yes	See Section E.6.19
38	Enhance FWS and ADS for long term injection	For Seismic-Induced Equipment Damage State SET-36 (Impacts - LOOP), enhance the Fire Water system and use the existing portable generator to support SRV operation for long term injection in seismic events.	IPEEE (Seismic)	N/A	No	Subsequent to the IPEEE, procedure HC.OP-AM.TSC-0024 was developed to address the actions associated with this SAMA. Therefore, this SAMA is screened from further analysis.
39	Provide procedural guidance to bypass RCIC turbine exhaust trip	Revise procedure to allow bypass of RCIC turbine exhaust pressure trip.	Industry SAMA List	$120,000	Yes	See Section E.6.20

TABLE E.5-3
HCGS PHASE 1 SAMA LIST SUMMARY

SAMA NUMBER	SAMA TITLE	SAMA DESCRIPTION	SOURCE	COST ESTIMATE [1]	RETAINED	PHASE 1 BASELINE DISPOSITION
40	Increase reliability / install manual bypass of LP permissive	Increase the reliability of the low pressure ECCS RPV low pressure permissive circuitry. Install manual bypass of low pressure permissive.	Industry SAMA List	$620,000	Yes	See Section E6.21

Notes:

[1] Cost estimates provided / validated by HCGS

TABLE E.5.4
SUMMARY OF HCGS PRA MODELING OF SEISMIC IMPACT ON BASELINE HEPS

OPERATOR ACTION DESCRIPTION [(1)]	HCGS PRA BASELINE HEP (BASIC EVENT ID)	HCGS IPE HEP	HCGS SEISMIC IPEEE HEP	HEP MODIFICATIONS IN HCGS PRA FOR SEISMIC INITIATORS
Failure to Provide Alternate Ventilation Within 12 Hours After Loss of Class 1E Panel Room HVAC	2.9E-3 (NR-HVC-PNRM-12) [(6)]	3.0E-4	3.0E-3	The frequency of seismic initiator %IE-SET38, as taken from the HCGS Seismic IPEEE, incorporates the increased HEP (3E-3) due to the seismic event. No HEP adjustment necessary in the HCGS PRA modeling. For other seismic initiators, operator action basic event NR-HVC-PNRM-SET, with a value of 3.0E-3, is used in the fault tree logic to replace the baseline 2.9E-3 HEP.
Failure to Provide Alternate Ventilation Within 24 Hours After Loss of Switchgear Room Ventilation	1.4E-2 (NRHVCSWGR24-01)	1.6E-4	1.0E-1	Operator action basic event NRHVCSWGR24-SET, with a value of 1.0E-1, is used in the fault tree logic to replace the baseline 1.4E-2 HEP.
Failure to Initiate RHR for Decay Heat Removal (Early)	3.1E-4 (NR-RHR-INIT)	5.0E-5	5.0E-4	Operator action basic event NR-RHR-INIT-SET, with a value of 5.0E-4, is used in the fault tree logic to replace the baseline 3.1E-4 HEP. Operator action basic event NR-RHR-INIT-SET also is used in the fault tree logic to replace basic event NR-RHR-INIT-L (Failure to Initiate RHR for DHR – Late) to replace the baseline 2.1E-6 HEP.
Failure to Align SACS for Long-Term Operation with One Operating SACS Pump in Each Loop	4.32E-3 (SAC-XHE-FO-XTIE) [(5)]	1.0E-2	1.0E-1	Operator action basic event SAC-XHE-FO-XTIE, with a value of 1.0E-1, is used in the fault tree logic to replace the baseline 4.32E-3 HEP.
Failure to Depressurize with SRVs	3.6E-4 (NR-U1X-DEP-SRV) [(2)]	[(2)]	[(2)]	Operator action basic event NR-U1X-DEP-SET, with a value of 1.0E-2, is used in the fault tree logic to replace the baseline 3.6E-4 HEP.

TABLE E.5.4
SUMMARY OF HCGS PRA MODELING OF SEISMIC IMPACT ON BASELINE HEPS

OPERATOR ACTION DESCRIPTION (1)	HCGS PRA BASELINE HEP (BASIC EVENT ID)	HCGS IPE HEP	HCGS SEISMIC IPEEE HEP	HEP MODIFICATIONS IN HCGS PRA FOR SEISMIC INITIATORS
Failure to Manually Initiate ECCS Within 1 Hour	3.8E-4 (NR-UV-ECCS-T)	3.9E-2	3.9E-1	Operator action basic event NR-UV-ECCS-SET, with a value of 3.9E-1, is used in the fault tree logic to replace the baseline 3.8E-4 HEP.
Failure to Control RPV Level With HPCI/RCIC – Not ATWS	8.27E-3 (NR-UV-WTLVL-20M)	4.3E-2	4.3E-1	Operator action basic event NR-UV-WTLVL-SET, with a value of 4.3E-1, is used in the fault tree logic to replace the baseline 8.27E-3 HEP.
Failure to Initiate Containment Venting	2.58E-3 (NR-VENT-5-03)	2.0E-3	3.0E-2	Operator action basic event NR-VENT-5-03, with a value of 3.0E-2, is used in the fault tree logic to replace the baseline 2.58E-3 HEP.
Failure to Manually Start SACS or SSWS Pumps	(3)	(3)	1.6E-1	Operator action basic event NR-WW1-SACSW-SET, with a value of 1.6E-1, is used in the fault tree logic to replace the baseline HEPs.
Failure to Recover Offsite Power	(4)	(4)	1.0	Operator action basic event NR-LOSP-SET, with a value of 1.0, is used in the fault tree logic to replace baseline HEPs for offsite power recovery in the shorter time frames (less than 4 hours). Operator action basic event NR-LOSP-SET4, with a value of 5.0E-1, is used in the fault tree logic to replace the baseline HEPs for offsite power recovery in the longer time frames (4 or more hours).
Failure to Safely Shutdown Plant Using Remote Shutdown Panel	N/A	N/A	6.3E-2	The frequencies of seismic initiators %IE-SET34 and %IE-SET35, as taken from the HCGS Seismic IPEEE, incorporate the Remote Shutdown Panel HEP (6.3E-2). No HEP adjustment necessary in the HCGS PRA modeling.

NOTES TO TABLE E.5.4:

(1) The list of operator action HEPs identified for potential modification for seismic initiators is based on the HCGS IPEEE seismic analysis.

(2) The HCGS Seismic IPEEE makes the following RPV emergency depressurization HEP modifications:

- NR-U1X-DEP-40M: HEP increased from 5.2E-3 to 5.2E-2
- NR-U1X-DEP-60M: HEP increased from 4.6E-3 to 4.6E-2

However, the two operator actions above are not used as the baseline RPV Emergency Depressurization HEP in the current HCGS PRA. The HCGS PRA currently uses basic event NR-U1X-DEP-SRV (with an HEP of 3.6E-4) to model RPV Emergency Depressurization for non-ATWS scenarios. As such, basic event NR-U1X-DEP-SRV is the event replaced in the PRA with a higher HEP for seismic initiators.

(3) There are four operator action basic events for failure to manually start a SACS or SSWS pumps:

- NR-WW1-SAC-02 (Replaced by basic event SAC-XHE-FS-AP210 in current HCGS PRA)
- NR-WW1-SAC-03 (Replaced by basic event SAC-XHE-FS-AP210 in current HCGS PRA)
- NR-WW1-SWP-02
- NR-WW1-SWP-03

In the HCGS IPEEE Table 3-9, these four actions are listed as having HEPs in the HCGS IPE ranging from 7.4E-5 to 1.6E-2, and are each increased to 1.6E-1 for the HCGS Seismic IPEEE. In the current HCGS PRA, the first two actions have been replaced by basic event SAC-XHE-FS-AP210. These actions have baseline HEPs of 8.28E-4, 2.16E-3, and 2.16E-3, respectively. Each of these three actio**ns** are replaced in the HCGS PRA with an HEP of 1.6E-2 (consistent with the HCGS IPEEE) for seismic initiators.

(4) Although offsite power recovery failure probability modifications are not described in the text of the HCGS IPEEE, review of the HCGS Seismic IPEEE supporting documentation (Report H-07, Seismic System Analysis/Quantification Report) shows no offsite power recovery basic events in the cutsets (indicating offsite power recovery was assumed to have a 1.0 failure probability for the HCGS Seismic IPEEE). The following five offsite power recovery actions are included in the current HCGS PRA models and filter up into seismic sequences:

- NR-LOSP-15M (6.8E-1): 15 minute time frame
- NR-LOSP-45M (3.9E-1): 45 minute time frame
- NR-LOSP-25 (1.3E-1): 2.5 hour time frame
- NR-LOSP-5 (5.3E-2): 5 hour time frame

For the seismic sequences, these offsite power recovery actions are increased as follows: The current HCGS PRA model credits long term offsite AC power recovery in the 4 and 20 hour time frames. The 5 hour time frame value of 5.0E-1 from the IPEEE is conservatively used for both the 4 and 20 hour time frames; and the values for the lesser time frames are replaced with an event with a value of 1.0.

(5) The HCGS Seismic IPEEE makes the following SACS alignment HEP modification:

- NR-SACS-SHED-01: HEP increased from 1.0E-3 to 1.0E-1

However, the operator action above is not used in the current HCGS PRA. The HCGS PRA currently uses basic event SACS-XHE-FO-XTIE (with an HEP of 4.32E-3) to SACS alignment and crosstie failure. As such, basic event SACS-XHE-FO-XTIE is the event replaced in the PRA with a higher HEP for seismic initiators.

(6) Operator action basic event NR-HVC-PNRM-SET is not modeled as a failure mode in the current HCGS PRA. It is included in this table for consistency with the IPEEE.

TABLE E.6-1
HCGS PHASE 2 SAMA LIST SUMMARY

SAMA NUMBER	SAMA TITLE	SAMA DESCRIPTION	SOURCE	PHASE 2 BASELINE DISPOSITION
1	Remove ADS inhibit from non-ATWS emergency operating procedures	Investigate the design basis for inhibiting ADS. If ADS does not have to be inhibited except for ATWS, it can be credited for reducing pressure in more scenarios. Susquehanna and LaSalle have taken this approach. An alternative solution is to install an injection system capable of operating at high pressures. However, this solution is a much costlier option and may likely prove not be a practical approach to mitigating this event.	HCGS Level 1 Importance List	The averted cost-risk for this SAMA is **greater** than the cost of implementation, therefore the SAMA is **cost beneficial**.
3	Install back-Up air compressor to supply AOVs	Provide a back-up air compressor to supply AOVs with an alternate air source.	HCGS Level 1 Importance List	The averted cost-risk for this SAMA is **greater** than the cost of implementation, therefore the SAMA is **cost beneficial**.
4	Provide procedural guidance to cross-tie RHR trains	Provide the ability to cross-tie RHR pumps trains. Although the piping network exists, it is not allowed by procedure.	HCGS Level 1 Importance List	The averted cost-risk for this SAMA is **greater** than the cost of implementation, therefore the SAMA is **cost beneficial**.
5	Restore AC power with onsite gas turbine generator	Improve procedural use of gas turbine generator to restore onsite emergency AC power sources.	HCGS Level 1 Importance List	The averted cost-risk for this SAMA is less than the cost of implementation and therefore the SAMA is not cost beneficial.
7	Install better flood detection instrumentation for RACS compartment	This HRE represents an internal flooding scenario that disables various safety-related components. Mitigation of this event can be accomplished by replacing manual isolation valves with remotely-operated MOVs with automatic isolation capability.	HCGS Level 1 Importance List	The averted cost-risk for this SAMA is less than the cost of implementation and therefore the SAMA is not cost beneficial.
8	Convert selected fire protection piping from wet pipe to dry pipe system	This HRE represents an internal flooding scenario that disables various safety-related components. Mitigation of this event can be accomplished by changing the existing FPS to a dry-pipe system. Limerick took this approach.	HCGS Level 1 Importance List	The averted cost-risk for this SAMA is less than the cost of implementation and therefore the SAMA is not cost beneficial.

TABLE E.6-1
HCGS PHASE 2 SAMA LIST SUMMARY

SAMA NUMBER	SAMA TITLE	SAMA DESCRIPTION	SOURCE	PHASE 2 BASELINE DISPOSITION
10	Provide procedural guidance to use B.5.b low pressure pump for non-security events	Since this involves loss of long-term RHR, provide an independent means of alternate makeup to RPV. Possible suction sources are CST, RST and FPS. Possible use of an alternate diesel-driven pump combined with rapid depressurization.	HCGS Level 1 Importance List	The averted cost-risk for this SAMA is **greater** than the cost of implementation, therefore the SAMA is **cost beneficial**.
15	Alternate design of CSS suction strainer to mitigate plugging	Consider alternate design of CSS suction strainer to mitigate plugging.	HCGS Level 1 Importance List	The averted cost-risk for this SAMA is less than the cost of implementation and therefore the SAMA is not cost beneficial.
16	Use of different designs for switchgear room cooling fans	Consider replacing one of the SWGR room cooling fans with a different design so as to eliminate common cause failure of all fans.	HCGS Level 1 Importance List	The averted cost-risk for this SAMA is less than the cost of implementation and therefore the SAMA is not cost beneficial.
17	Replace a supply fan with a different design in service water pump room	Consider replacing one of the SW pump room supply fans with a different design so as to eliminate common cause failure of all fans.	HCGS Level 1 Importance List	The averted cost-risk for this SAMA is **greater** than the cost of implementation, therefore the SAMA is **cost beneficial**.
18	Replace a return fan with a different design in service water pump room	Consider replacing one of the SW pump room return fans with a different design so as to eliminate common cause failure of all fans.	PRA Group Insight	The averted cost-risk for this SAMA is **greater** than the cost of implementation, therefore the SAMA is **cost beneficial**.
30	Provide procedural guidance for partial transfer of control functions from control room to the remote shutdown panel	For fires that cause catastrophic damage to the controls of a single critical system, the reliability of controling the plant may be improved by allowing the operators to transfer only a single division of controls to the RSP to recover a channel of the critical system while the MCR is maintained as the primary control center. A permutaiton of this SAMA would be to use local system controls rather than the RSP.	IPEEE (Fire)	The averted cost-risk for this SAMA is **greater** than the cost of implementation, therefore the SAMA is **cost beneficial**.

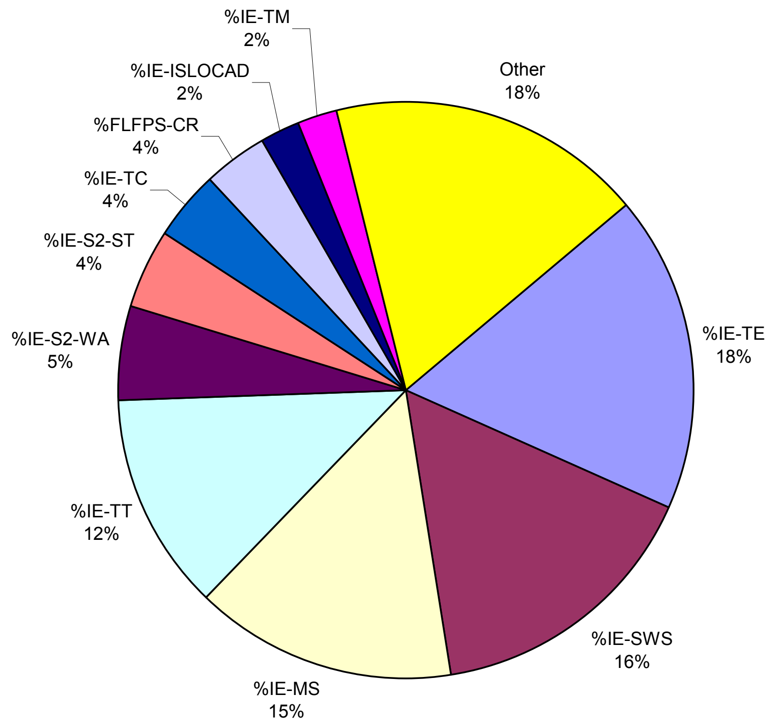
TABLE E.6-1
HCGS PHASE 2 SAMA LIST SUMMARY

SAMA NUMBER	SAMA TITLE	SAMA DESCRIPTION	SOURCE	PHASE 2 BASELINE DISPOSITION
31	Install improved fire barriers in the MCR control cabinets containing the primary MSIV control circuits	MCR fires that propagate from the originating cabinets result in widespread control damage and induce environmental conditions that would require abandonment even if the controls were not damaged. IPEEE insights suggest that improving the fire barriers in the console containg the primary MSIV controls would reduce the probability of these types of fire events.	IPEEE (Fire)	The averted cost-risk for this SAMA is less than the cost of implementation and therefore the SAMA is <u>not</u> cost beneficial.
32	Install additional physical barriers to limit dispersion of fuel oil from DG rooms	For compartment 5339 fire scenario 5339_2, install a curb or a diversion channel to ensure liquids from the DG rooms cannot communicate with Room 5339.	IPEEE (Fire)	The averted cost-risk for this SAMA is less than the cost of implementation and therefore the SAMA is <u>not</u> cost beneficial.
33	Install Division II 480VAC bus crossties	For DG room (D) fire scenario 5304_2, install cross-ties between the Division II 480VAC buses (potentially 10B420 to10B480 and 10B460 to 10B440).	IPEEE (Fire)	The averted cost-risk for this SAMA is less than the cost of implementation and therefore the SAMA is <u>not</u> cost beneficial.
34	Install Division I 480VAC bus crossties	For DG room (C) fire scenario 5306_2, install cross-ties between the Division I 480VAC buses (potentially 10B410 to10B430 and 10B450 to 10B470).	IPEEE (Fire)	The averted cost-risk for this SAMA is less than the cost of implementation and therefore the SAMA is <u>not</u> cost beneficial.
35	Relocate, minimize, and/or eliminate electrical heaters in electrical access room	For compartment 3425/5401 fire scenario 5401_1, move or eliminate the electrical heaters in the electrical access room (Aux Building 124' level) to prevent damage to the Division II power cables.	IPEEE (Fire)	The averted cost-risk for this SAMA is **greater** than the cost of implementation, therefore the SAMA is **cost beneficial**.
36	Provide procedural guidance for loss of all 1E 120V AC power	For Seismic-Induced Equipment Damage State SET-36 (Impacts - 120V PNL481), develop MCR procedures to operate the plant after a loss of all class 1E 120V AC power.	IPEEE (Seismic)	The averted cost-risk for this SAMA is less than the cost of implementation and therefore the SAMA is <u>not</u> cost beneficial.

TABLE E.6-1
HCGS PHASE 2 SAMA LIST SUMMARY

SAMA NUMBER	SAMA TITLE	SAMA DESCRIPTION	SOURCE	PHASE 2 BASELINE DISPOSITION
37	Reinforce 1E 120V AC distribution panels	For Seismic-Induced Equipment Damage State SET-36 (Impacts - 120V PNL481), reinforce the class 1E 120V AC distribution panels.	IPEEE (Seismic)	The averted cost-risk for this SAMA is less than the cost of implementation and therefore the SAMA is not cost beneficial.
39	Provide procedural guidance to bypass RCIC turbine exhaust pressure trip	Revise procedure to allow bypass of RCIC turbine exhaust pressure trip.	Industry SAMA List	The averted cost-risk for this SAMA is **greater** than the cost of implementation, therefore the SAMA is **cost beneficial**.
40	Increase reliability / install manual bypass of LP permissive	Increase the reliability of the low pressure ECCS RPV low pressure permissive circuitry. Install manual bypass of low pressure permissive.	Industry SAMA List	The averted cost-risk for this SAMA is less than the cost of implementation and therefore the SAMA is not cost beneficial.

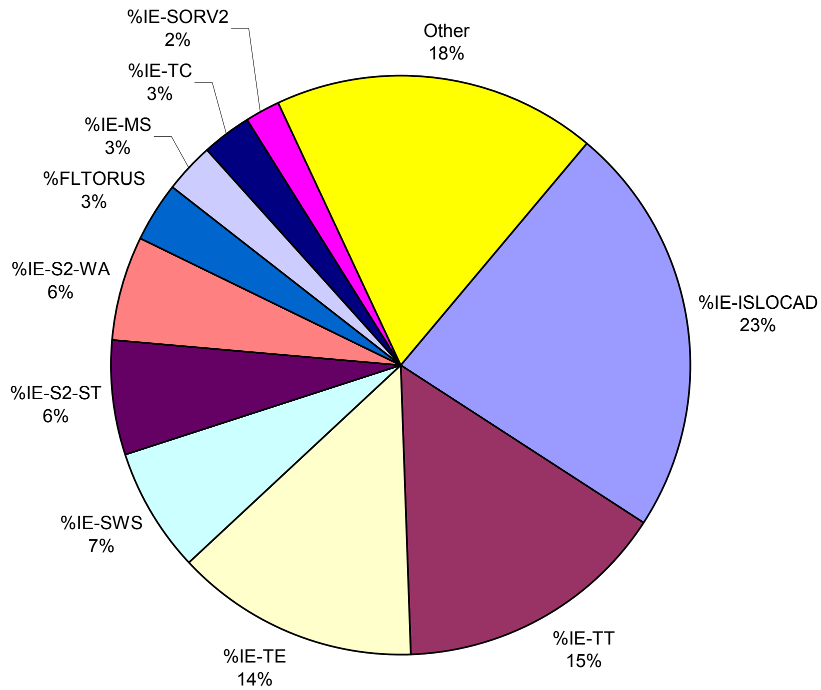
E.10 FIGURES



Basic Event ID	Description
%IE-TE	LOSS OF OFFSITE POWER INITIATING EVENT
%IE-SWS	LOSS OF SERVICE WATER INITIATING EVENT
%IE-MS	MANUAL SHUTDOWN INITIATING EVENT
%IE-TT	TURBINE TRIP WITH BYPASS
%IE-S2-WA	SMALL LOCA - WATER (BELOW TAF)
%IE-S2-ST	SMALL LOCA - STEAM (ABOVE TAF)
%IE-TC	LOSS OF CONDENSER VACUUM
%FLFPS-CR	FPS RUPTURE OUTSIDE CONTROL ROOM
%IE-ISLOCAD	ISLOCA INITIATOR FOR ECCS DISCHARGE PATHS
%IE-TM	MSIV CLOSURE

Note: For complete listing of IEs contributing to CDF, see Table E.2-5

FIGURE E.2-1
HC108B CONTRIBUTION TO CDF BY INITIATING EVENT



Basic Event ID	Description
%IE-ISLOCAD	ISLOCA INITIATOR FOR ECCS DISCHARGE PATHS
%IE-TT	TURBINE TRIP WITH BYPASS
%IE-TE	LOSS OF OFFSITE POWER INITIATING EVENT
%IE-SWS	LOSS OF SERVICE WATER INITIATING EVENT
%IE-S2-ST	SMALL LOCA - STEAM (ABOVE TAF)
%IE-S2-WA	SMALL LOCA - WATER (BELOW TAF)
%FLTORUS	TORUS RUPTURE IN TORUS ROOM
%IE-MS	MANUAL SHUTDOWN INITIATING EVENT
%IE-TC	LOSS OF CONDENSER VACUUM
%IE-SORV2	2 or More SORVs

Note: For complete listing of IEs contributing to LERF, see Table E.2-2

FIGURE E.2-2
HC108B CONTRIBUTION TO LERF BY INITIATING EVENT

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