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May 6, 2011
GO2-11-092

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

Subject: **COLUMBIA GENERATING STATION, DOCKET NO. 50-397 RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION RELATED TO THE REVIEW OF THE SEVERE ACCIDENT MITIGATION ALTERNATIVE ANALYSIS**

References:
1) Letter, GO2-10-011, dated January 19, 2010, WS Oxenford (Energy Northwest) to NRC, "License Renewal Application"

2) Letter, GO2-11-032, dated January 28, 2011, SK Gambhir (Energy Northwest) to NRC, "Response to Request for Additional Information for the Review of the Columbia Generating Station License Renewal Application"

3) Letter dated March 10, 2011, NRC to SK Gambhir (Energy Northwest), "Request for Additional Information for the Review of the Columbia Generating Station License Renewal Application – Severe Accident Mitigation Alternative Review," (ADAMS Accession No. ML110670379)

Dear Sir or Madam:

By Reference 1, Energy Northwest requested the renewal of the Columbia Generating Station (CGS) operating license. In Reference 2, Energy Northwest submitted responses to several Requests for Additional Information (RAIs) related to the Severe Accident Mitigation Alternative (SAMA) analysis and provided the results of a sensitivity study performed using the Integrated Probabilistic Safety Analysis (PSA) Model Revision 7.1. Via Reference 3, the Nuclear Regulatory Commission (NRC) requested additional information pertaining to the sensitivity study provided in Reference 2. Transmitted herewith in Attachment 1 is the Energy Northwest response to the RAIs contained in Reference 3. No additional SAMA candidates have been identified for implementation. Enclosure 1 contains Amendment 34 to the License Renewal Application (LRA) that was submitted in Reference 1.

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No new commitments are included in this response.

If you have any questions or require additional information, please contact Abbas Mostala at (509) 377-4197.

I declare under penalty of perjury that the foregoing is true and correct. Executed on the date of this letter.

Respectfully,

D. A. Swank
Acting Vice President, Engineering

Attachment 1: Response to Request for Additional Information
Attachment 2: Revised Tables for the PSA Rev. 7.1 Sensitivity Study
Enclosure 1: Amendment 34 to the LRA

cc: NRC Region IV Administrator
NRC NRR Project Manager
NRC Senior Resident Inspector/988C
EFSEC Manager
RN Sherman – BPA/1399
WA Horin – Winston & Strawn
D Doyle - NRC NRR (w/a)
BE Holian - NRC NRR
RR Cowley – WDOH

NRC Request:

1. Table B-4 does not provide an analysis of SAMA CC-21, which was screened as Criterion C. If modeled similar to SAMA CP-01, SAMA CC-21 (procedure change) would be cost-beneficial. Clarify the disposition of this SAMA.

Energy Northwest Response:

Severe Accident Mitigation Alternative (SAMA) candidate CC-21 proposes to revise procedures to align condensate to the low pressure injection subsystems as an alternate source of vessel inventory control should the suppression pool become too hot to support low pressure injection due to loss of pump suction head. This candidate was originally screened as Criterion C – Considered for Further Evaluation in Table E.10-1 of the ER (Reference A). However, this SAMA candidate was not included in the cost benefit evaluation and no further discussion was provided.

There are three existing water sources that are available as alternative sources for injection: (i) service water (SW) from the spray ponds, (ii) fire water from the circulating water basin, and (iii) condensate from the hotwell with makeup from the condensate storage tank (CST). Each method will be discussed below.

i. SW cross-connect to the residual heat removal (RHR) system for vessel injection is a standard BWR design and contained in emergency procedures.

ii. Fire water has two pathways for injection: (a) The main fire water system (diesel and electric pumps) can be cross-tied to a condensate booster pump connection and supplied to the reactor pressure vessel by utilizing the feedwater pump bypass line. This injection source is contained in emergency procedures. (b) A fire hose can be connected to the 6 inch lines on the low pressure coolant injection (LPCI) piping through removal of a blind flange. The connection points to the three LPCI loops are available for injection by pumper truck with fire water. The use of the 6 inch pathways are allowed under the Columbia Generating Station (CGS) extensive damage mitigation guidelines using fire water with the pumping force provided by a pumper truck. (Note: There is a spool piece connection to this blind flange that connects LPCI to the condensate system, but this is only used for refilling and flushing the lines after maintenance). Providing procedures for connection to condensate would provide very little benefit because pumping power is required to reach these connections points.

iii. Condensate from the hotwell and CST has multiple pathways for injection. Assuming power is available to the condensate pumps or to the condensate and condensate booster pumps, the injection pathway is discharged directly to the vessel via the feedwater pump bypass lines. This injection pathway from the condenser hotwell to the reactor vessel is currently in CGS emergency

procedures. Emergency procedures also contain the ability to inject fire water to the condenser hotwell for additional inventory.

Additionally, since CGS has a direct gravity drain from the CST to the diesel-backed motor driven high pressure core spray (HPCS) pump (which can supply injection at high and low pressure) and the steam driven reactor core isolation and cooling (RCIC) pump, the CST inventory would only be available to the low pressure pumps on loss of these systems prior to CST inventory depletion.

It is noted that CGS has an abandoned 18 inch cross-connect from condensate to the suction of LPCI loop C. This connection has a blind flange installed to address concerns associated with secondary containment liquid bypass pathways. Use of this pathway for SAMA would require either draining of LPCI loop C to remove the blind flange or a plant modification to be able to isolate LPCI loop C for removal of the blind flange. It would also require condensate system pumping power which, if available, would be used as described above to inject into the vessel. Further, this pathway would only benefit Division 2 injection systems. Thus, this potential injection pathway would provide very little additional risk mitigation. There is also a potential risk increase for any of the low pressure injection pathways from other than the suppression pool in the event of re-pressurizing due to loss of depressurization control.

Thus, the screening criterion for SAMA candidate CC-21 is being revised to Criterion B – Already Implemented, since the capability to provide alternate injection sources through multiple pathways currently exists and is proceduralized using SW, fire water and condensate for core cooling.

NRC Request:

2. Tables A-10, A-12, and A-14 provide a large early release frequency (LERF) importance analysis for internal, fire, and seismic events, respectively, and associated SAMA assessment. Tables A-6 through A-7 show that release category M/I is generally a much more significant contributor to population dose/economic impact than the LERF (H/E) release category, with release category H/I also being a significant contributor. Clarify how releases categories M/I and H/I are considered in the LERF importance analysis.

Energy Northwest Response:

Release categories M/I and H/I are not specifically considered in the LERF importance analysis. Therefore, a review was performed of basic event importance derived from release categories H/I and M/I to determine if additional SAMA candidates should be considered based on these release categories.

Most of the important basic events applicable to H/I and M/I have already been reviewed in either the Level 1 or the LERF (H/E) basic event importance reviews (Tables A-9 through A-14 in Reference F). When applying the risk reduction worth (RRW) benefit to the basic events in these tables, if the event appeared in the Tables A-10, A-12, or A-14, the maximum benefit from the Level 1 core damage frequency (CDF) was used as a bounding value to derive a LERF contribution for screening purposes. The LERF RRW benefit was based on the maximum CGS benefit by hazard (i.e., Internal Events - $500,446, Fire - $863,256, Seismic - $436,020) rather than that portion of the benefit attributed to the LERF (H/E) release category (i.e., Internal Events - $45,805, Fire - $5,452, Seismic - $234,032). This conservative treatment of LERF was utilized in lieu of applying an exhaustive treatment by individual release category (twenty-seven tables of basic events consisting of the three hazards and nine release categories).

In reviewing the basic events identified from the H/I and M/I release categories, a bounding maximum benefit by release category was derived as follows: the release category frequency was multiplied by the consequence associated with the release category to estimate the annual off-site dose and annual off-site economic impact by release category. The annual off-site dose and annual off-site economic impact for a given release category are used to estimate the averted public exposure (APE) and averted off-site property damage costs (AOC). The next step estimated the averted occupational exposure (AOE) and the averted on-site costs (AOSC) by release category. The methodology used the total frequency for a given release category in the estimate of AOE and AOSC, rather than the total CDF. By modifying these aspects of the calculation, a "maximum" benefit per release category was determined as tabulated in Table 2-1.

Table 2-1: Maximum Benefit by Release Category

Release Category	Maximum Benefit ($)		
	Internal Events	Fire	Seismic
OK	$66,500	$123,834	$19,412
H/E	$45,805	$5,452	$234,032
H/I	$25,223	$8,519	$65,417
M/E	$15,861	$1,277	$323
M/I	$315,445	$661,862	$86,643
L/E	$2,205	$2,230	$470
L/I	$298	$657	$56
LL/E	$6,294	$33,062	$4,962
LL/I	$22,819	$26,262	$24,600
Total[1]	$500,450	$863,155	$435,915

[1]The difference in total maximum benefit between Table 2-1 and that reported in Reference F is due to round-off approximations.

When deriving the RRW benefit for basic events that appear only in the Level 2 model (that is, don't appear in the Level 1 CDF model), a bounding assumption was made that the accident sequences that contribute to the releases were eliminated rather than transferring to Containment OK, and thus a higher benefit was obtained.

Table 2-2 contains an assessment of H/I and M/I basic events meeting either one of the following criteria: 1) basic events that were below the importance cutoff for Tables A-9 through A-14 from Reference F but above the cutoff for the H/I and M/I release categories, or 2) basic events whose RRW benefit associated with the H/I or M/I release categories exceeded the RRW benefit derived for the Table A-9 through A-14 resolution sufficient to cause a change in that screening resolution or basis. Basic events that are modeling flags or post-CDF phenomenological events, which are not conducive to a SAMA candidate, are not included in the table. This review identified no new SAMA candidates but did identify additional human error basic events for consideration in operator training enhancement.

Table 2-2: Additions to Basic Events Importance List for Release Categories H/I and M/I

Event Label	Description	Hazard	RRW	Point Estimate	Resolution
SWS-XHE-FO-L2SWN	Fail to switch to alternate injection sources outside Reactor Building	Seismic (S)-M/I Internal Events (IE)-M/I Fire (F)-M/I	1.31 1.092 1.043	7.10E-01	SAMA candidate OT-07R evaluates improving procedures and operator training on systems and operator actions determined to be important from probability safety assessment (PSA) results. This SAMA candidate was previously found to be cost-beneficial. This operator action will be included under SAMA candidate OT-07R. No additional SAMA candidates are required.
IE-FLD-C507TSW-M	Major plant service water (TSW) pipe break in C507	IE-M/I	1.049	1.39E-06	SAMA candidate FL-06R, which provides additional non-destructive examination (NDE) and inspections, detects line degradation and reduces the flooding frequency. This flooding initiator was included in the modeling. This candidate was evaluated for cost-benefit. No additional SAMA candidates are required.
IE-FLD-C508TSW-M	Major TSW pipe break in C507	IE-M/I	1.049	1.39E-06	SAMA candidate FL-06R, which provides additional NDE and inspections, detects line degradation and reduces the flooding frequency. This flooding initiator was included in the modeling. This candidate was evaluated for cost-benefit. No additional SAMA candidates are required.
DEP-CRD-SPCST---	Operator fails to align standby control rod drive (CRD) train and suppression pool cooling (SPC) early	IE-M/I	1.04	8.10E-06	SAMA candidate OT-07R evaluates improving procedures and operator training on systems and operator actions determined to be important from PSA results. This SAMA candidate was previously found to be cost-beneficial. This operator action will be included under SAMA candidate OT-07R. No additional SAMA candidates are required.
FT1D	Fire initiating event in fire zone T1D	F-M/I	1.018	9.88E-03	SAMA candidate FR-12R evaluates the installation of early detection in this fire area. This fire initiator was included in the modeling. This candidate was evaluated for cost-benefit. No additional SAMA candidates are required.
IFT1D	Fixed ignition source fraction in fire zone T1D	F-M/I	1.018	9.46E-01	SAMA candidate FR-12R evaluates the installation of early detection in this fire area. This candidate was evaluated for cost-benefit. No additional SAMA candidates are required.

Table 2-2: Additions to Basic Events Importance List for Release Categories H/I and M/I

Event Label	Description	Hazard	RRW	Point Estimate	Resolution
L2-PHE-RXENV-PMP	Reactor Building environment fails residual heat removal (RHR) pump injection	F-M/I IE-M/I	15.168 7.781	9.98E-01	This basic event assumes an environmental condition beyond the RHR equipment's environmental qualification due to an accident. Hardening RHR equipment to meet or approach the in-containment accident environmental profile survival is not possible. Having low pressure injection sources outside of the reactor building, such that they are not impacted environmentally by the accident is available at CGS. As discussed in RAI 1 for SAMA candidate CC-21, CGS has the ability to provide injection from the service water system, the fire water system, the condensate system, and by a fire pumper truck. This SAMA candidate is already implemented. No additional SAMA candidates are required.
SEIS-PDS-V-DCPOW	DC power not available following seismic plant damage state V (core damage and containment bypass caused by seismic induced failures of the RPV and/or key buildings)	S-H/I	1.306	6.00E-01	CGS has a portable diesel generator (DG-4) that can provide DC power during a station blackout (SBO). However, given the beyond design basis earthquake sufficient to cause seismic-induced failure of key plant buildings, equipment contained within them are also assumed not available. If equipment does survive, DG-4 would be a means to provide power to the battery chargers. In addition, SAMA candidates AC/DC-01, AC/DC-02, and AC/DC-03 evaluate improving battery lifetime. These candidates were evaluated for cost-benefit. SAMA candidates AC/DC-04 and AC/DC-05 evaluate increased availability of DC systems. These candidates were evaluated in Reference F Table A-16. No additional SAMA candidates are required.

Table 2-2: Additions to Basic Events Importance List for Release Categories H/I and M/I

Event Label	Description	Hazard	RRW	Point Estimate	Resolution
L2-PHE-HRHURHRRC	SPC not recovered during Level 2 progression	IE-M/I	1.142	9.00E-01	This is a human failure event to recover suppression pool cooling (SPC) during Level 2 progressions. Modeling of the SPC unavailability for Level 1 does not include this late recovery basic event. Given the longer time frame for potential recovery during the Level 2 progressions, a 0.1 recovery likelihood (the complement of 0.9) is modeled. This modeling reflects a low estimated likelihood for recovery, given the potentially high radiation levels that may limit local recovery actions or other potential severe accident issues. The plant response on loss of SPC cooling (not immediately recoverable) and inability to maintain suppression pool temperature below the heat capacity temperature limit (HCTL) will be to emergency depressurize. If unable to maintain containment pressure below the pressure suppression pressure (PSP) limit, the containment will be vented. Thus, this SAMA candidate is already implemented. Repair and restoration of SPC would be a high priority of the emergency response team process. No further SAMA candidates are required.
L2-PHE-AC-TD-FS1	Fail to recover AC power prior to containment failure (Fire)	F-M/I	1.069	1.00E+00	Fire / seismic losses of AC power are assumed to not be recoverable. Not applicable as a SAMA candidate.
L2-PHE-AC-TD-FS2	Fail to recover AC power prior to containment failure (Seismic)	S-H/I	1.438	1.00E+00	Fire / seismic losses of AC power are assumed to not be recoverable. Not applicable as a SAMA candidate.
L2-PHE-DI6-FAIL	Drywell fails given NC=F and high pressure core spray (HPCS) fails (loss of decay heat removal sequence)	IE-M/I F-M/I S-M/I	1.800 1.882 1.633	5.00E-01	SAMA candidate CC-02, which provides additional high pressure injection capability, increases high pressure injection availability. SAMA candidate CP-01, which provides addition SPC capability, reduces containment failure probability. These candidates were evaluated for cost-benefit. No additional SAMA candidates are required.

NRC Request:

3. The Level 1 and Level 2 seismic basic events importance lists (Tables A-13 and A-14) identify, in addition to the two initiating events, only a few basic events, and those identified appeared to be flag events, split fractions, or success terms. Neither seismically-induced failures nor random failures appear to be addressed in this importance analysis. Clarify how the seismic importance lists were developed. In the response, specifically discuss how the seismic probabilistic safety assessment (PSA) model treats both seismically-induced failures and random failures. If random failures are not included in the seismic analysis, explain how this model incompleteness impacts the SAMA evaluation.

Energy Northwest Response:

Random failures are included in the Seismic PSA model, but these did not rise above the importance cutoff level (for RRW benefit) to be included in Tables A-13 and A-14.

The seismic importance list from the Integrated PSA Model Rev. 7.1 was developed using the output of the WinNUPRA software program. The software contains a module that calculates importance metrics, including RRW, for all basic events that appear in the seismic PSA cutsets. The RRW benefit value for the cost of a procedure change ($12K) was determined using the maximum benefit for seismic events for Level 1 and LERF. Those basic events with an RRW benefit value equal to or greater than the cost of a procedure change at CGS were provided in Table A-13 and A-14 of Reference F.

NRC Request:

4. Table A-1 presents a total fire core damage frequency (CDF) of 3.6E-6/yr on the Rev. 6.2 Model column header, but the contributing fire sequences under that column header sum to 3.92E-6/yr. Environmental Report Table E.3-1, on the other hand, presents a total fire CDF of 7.4E-6/yr and Table E.4-5 presents release categories that appear to support (i.e., frequencies when summed equals 7.4E-6/yr) that total. Clarify these discrepancies.

Energy Northwest Response:

The total Fire CDF reported in Reference F Table A-1 (Fire) for PSA Rev. 6.2 is incorrect. This issue has been entered into the Energy Northwest corrective action program. The correct value for total Fire CDF is 7.4E-6/yr. A corrected Table A-1 (Fire) is provided in Attachment 2.

NRC Request:

5. The truncation limits for internal events, fire and seismic models used in the quantification of Revision 6.2 Level 1 and Level 2 CDFs range from 5×10^{-14} to 1×10^{-8}. In response to an NRC staff RAI (Sept. 17, 2010) Energy Northwest explained that in general a four-order difference between the calculated total and truncation limit was maintained, except in a few cases where a lesser difference was appropriate. In a telephone clarification, EN further explained that the expression "appropriate" referred to cases in which the calculated CDF appeared to converge using a lower truncation limit. Clarify if the following statement is applicable for both the Revision 6.2 and 7.1 PSA models: "In general a four-order-of-magnitude difference between the calculated total and truncation limit was maintained, except in a few cases where a lower truncation limit resulted in convergence between the calculated CDF and truncation limit."

Energy Northwest Response:

For Revision 6.2 of the PSA, a four-order-of-magnitude difference between the calculated total and truncation limit was maintained except in a few cases where a lower truncation limit resulted in convergence between the calculated CDF and truncation limit. For Revision 7.1 of the PSA, at least four orders of magnitude difference between the calculated total and truncation limit was maintained.

NRC Request:

6. The fire events listed in Table A-1 are almost entirely different from the fire events listed in Table E.3-7 of the Environmental Report. It appears that the Table A-1 fire events are identified by initiating event category rather than fire compartment (although the Table A-1 column header uses the term "Fire Compartment"). Clarify the difference between the fire events listed in the Environmental Report and table A-1 of the RAI response.

Energy Northwest Response:

The fire compartment labels used in Reference F Table A-1 (Fire) are different from those used in in the Environmental Report (ER) Table E.3-7. A footnote is added to Table A-1 (Fire) providing a cross-reference between the fire compartment labels. The footnote is included with the table provided in Attachment 2.

NRC Request:

7. Additional Comment #2 discussed in the January 19, 2011, conference call (ADAMS Accession Number ML110400510) does not appear to have been addressed. The Phase I screening for SAMAs AC/DC-05, CB-02, CB-05, CC-13, and FR-02 need to be re-evaluated based on the total risk reduction benefit and associated implementation cost.

Energy Northwest Response:

Columbia specific estimates for the cost of implementation for SAMA candidates AC/DC-05, CB-02, CB-05, CC-13, and FR-02 have been developed. The entries in Table A-16 have been revised to reflect the revised implementation costs. Corrected pages from Table A-16 have been provided in Attachment 2.

NRC Request:

8. Comment #2 discussed in the January 19, 2011, conference call (ADAMS Accession Number ML110400510) does not appear to have been entirely addressed. Explain the reason for the increase in fire population dose risk for SAMAs CW-02, CW-03, and CW-04 (Analysis Cases 18 and 19 in Table B-3) and the increase in internal events CDF and population dose-risk for SAMA AC/DC-30R (Analysis Case 45 in Table B-2).

Energy Northwest Response:

The increase in fire population dose risk for SAMA candidates CW-02, CW-03 and CW-04 results from a redistribution of plant damage state (PDS) frequencies computed by the event tree quantifications. When an event tree branch failure probability decreases as a result of a mitigation alternative, the corresponding success branch probability increases. These changes in the branch point probabilities increase some PDS frequencies and decrease others.

This redistribution of PDS frequencies for SAMA candidates CW-02, CW-03 and CW-04 produces net increases in the frequencies for release in the Level 2 PSA quantification, and thus increases in population dose risks.

PDS 1B0, in particular, is higher for CW-02, CW-03 and CW-04, by about 1E-6/rx-year. PDS 1B0 involves loss of decay heat removal scenarios. For PDS 1B0, all available injection systems have been previously credited in the Level 1 analysis, and the Level 2 PSA provides minimal credit for recovery of injection systems. The net result is a net increase in the frequency for release and an increase in fire population dose risk.

This phenomenon is more likely to occur when the delta-CDF is relatively small, and it is more likely for Fire PSAs. Since some event failure branch probabilities are relatively high due to fire impacts, the corresponding changes in success branch probabilities are larger when mitigation alternatives are examined.

For SAMA candidate AC/DC-30R, incorrect impact vectors were discovered to have been used. This issue has been entered into the Energy Northwest corrective action program. The Phase 2 calculation for AC/DC-30R was corrected and those portions of Tables B-1, B-2, B-3, B-4, B-5, B-7 and B-8 containing the results for AC/DC-30R are provided in Attachment 2. Based on the corrections, there were no changes to the disposition of AC/DC-30R.

NRC Request:

9. The calculated total for the internal, fire, and seismic events listed for the release categories presented in Tables A-3, A-4, and A-5 (5.61E-06/yr, 1.02E-05/yr, and 4.31E-06/yr respectively) are not the same as the total CDFs given for internal, fire, and seismic events in Table A-1 (7.4E-6/yr, 1.4E-6/yr, and 4.9E-6/yr respectively). Explain these differences. Also, the percentage contributions presented in Tables A-3, A-4, and A-5 total to much less than 100% for each table (e.g., totals to 75% in the case of the internal events release categories).

Energy Northwest Response:

The "Containment OK" category frequencies were not correctly reported in Tables A-3, A-4, and A-5 in Reference F (they were shown with frequencies of zero.) This issue has been entered into the Energy Northwest corrective action program. The Containment OK category frequencies are computed and have been placed in revised Tables A-3, A-4, and A-5, which are provided in Attachment 2.

NRC Request:

10. Table A-1 (seismic) shows that the CDF for a couple of the seismic damage states (i.e., S2P2, S20P2) was completely eliminated in PSA Rev. 7.1. Explain.

Energy Northwest Response:

S2P2 and S20P2 are seismic station blackout (SBO) event trees with RCIC successful. The RCIC system success criteria in PSA Rev. 7.1 require success of the condensate storage tank, which is failed by the modeled seismic events. Therefore all of the S2P2 and S20P2 accident sequence cutsets transfer to the seismic SBO event trees with RCIC unavailable, S2P3 and S20P3.

NRC Request:

11. Section 2.2 provides a sensitivity analysis of the assumed 0.3 hot short probability (if CPTs were known to be present for the circuits; otherwise, 0.6) for three selected SAMAs that address fire events. The basis for selecting the three SAMAs is the RRW significance of the hot shorts they address and that they address numerous important functions. Clarify Energy Northwest's basis for believing that the sensitivity analysis results for these three SAMAs bound the effect for other fire SAMAs. In the response, specifically address the potential for multiple hot shorts in series and whether the factor of 2 impact determined for SAMA FR-07b is bounding for the fire SAMAs. Alternatively, specifically assess the impact of using a 0.6 hot short probability (or 0.3 if these circuits are known to be protected by CPTs) on the analysis results for fire-related SAMAs FR-08, FR-09R, FR-12R, and FR-11R.

    Also, the hot short probability assumption could result in an underestimate of the estimated risk reduction for SAMAs identified principally to address internal events if the SAMA addresses cutsets that contain hot shorts. Assess the impact of using a 0.6 hot short probability (or 0.3 if these circuits are known to be protected by CPTs) on the analysis results for non-fire-related SAMAs AC/DC-15, AC/DC-23, AC/DC-27, CC-02, CP-01, CW-02, CW-07, CC-24R, FW-05R, and OT-09R, which have significant fire risk reduction contribution to the total estimated benefit.

Energy Northwest Response:

To provide additional confidence that the use of the 95th percentile uncertainty factor recommended in NEI 05-01, "Severe Accident Mitigation Alternatives (SAMA) Analysis Guidance Document," sufficiently bounds the parametric uncertainty associated with hot short probabilities, the additional SAMA candidates specified above were quantitatively evaluated using the following approach (consistent with that in Reference F):

i) For selected hot short events (nine total), a circuit evaluation was performed to verify that a control power transformer (CPT) was present. The hot short probabilities for these nine hot short events remained at 0.3 in the model, which is the highest best estimate value for circuits with a CPT per NUREG/CR-6850 "EPRI/NRC-RES Fire PRA Methodology for Nuclear Power Facilities."

ii) For all other hot short events, a circuit evaluation was not performed, and the model was modified to revise the remaining hot shorts to a probability of 0.6, which is the highest best estimate value for circuits without a CPT per NUREG/CR-6850. This sensitivity evaluation is judged to be a bounding calculation for this model incompleteness.

The sensitivity evaluation results are shown in Table RAI-11-1. The largest delta-CDF factor increase produced by the sensitivity evaluation was 1.38 (SAMA candidate CC-24R), which is well within the Fire uncertainty factor of 2.6. There were no changes to Internal Events and Seismic delta-CDFs as only the fire hazard component was affected. This sensitivity demonstrates that the parametric uncertainty associated with hot shorts does not alter the cost-beneficial conclusions. Therefore, no further evaluation of the SAMA cases is performed.

Table RAI-11-1 Hot Short Probability Sensitivity Evaluation for Additional SAMA Candidates

SAMA Candidate	Description	Base Fire CDF	Sensitivity Fire CDF	Original Fire Delta-CDF	Sensitivity Fire Delta-CDF	Delta-CDF Factor Increase
AC/DC-10-I	Provide an additional diesel generator.	1.37E-05	1.43E-05	1.34E-6	1.35E-6	1.01
AC/DC-23-I	Develop procedures to repair or replace failed 4 kV breakers	1.37E-05	1.43E-05	2.60E-7	2.60E-7	1.00
AC/DC-27-I	Install permanent hardware changes that make it possible to establish 500 kV backfeed through the main step-up transformer	1.37E-05	1.43E-05	5.23E-6	5.72E-6	1.09
CC-02-I	Provide an additional high pressure injection pump with independent diesel	1.37E-05	1.43E-05	1.02E-5	1.08E-5	1.06
CP-01-I	Install an independent method of suppression pool cooling	1.37E-05	1.43E-05	7.37E-6	7.59E-6	1.03
CW-02-I	Add redundant DC control power for pumps	1.37E-05	1.43E-05	7.20E-7	6.60E-7	0.92[1]
CW-07-I	Add a service water pump	1.37E-05	1.43E-05	1.74E-6	1.78E-6	1.02
CC-24R-I	Evaluate revising procedures to backfeed the high pressure core spray (HPCS) system with SM-8 to provide a third power source for HPCS	1.37E-05	1.43E-05	1.28E-6	1.77E-6	1.38
FW-05R-I	Examine potential for operators to control reactor feedwater (RFW) and avoid trip	1.37E-05	1.43E-05	9.60E-7	9.60E-7	1.00
FR-09R-I	Install early fire detection in the following reactor building physical analysis units: R-1B, R-1D, R-1J, R-1L, R-1C, R-1K	1.37E-05	1.43E-05	2.12E-6	2.21E-6	1.04
FR-08-I	Protect RHR and SW cables from fires	1.37E-05	1.43E-05	7.71E-6	8.23E-6	1.07
OT-09R-I	For the non-loss of coolant accident (LOCA) initiating events, credit the Z (PCS recovery) function	1.37E-05	1.43E-05	1.14E-6	1.14E-6	1.00
FR-12R-I	Install early fire detection in the following physical analysis units: T-1A, T-12, T-1C, T-1D	1.37E-05	1.43E-05	1.70E-6	1.70E-6	1.00
FR-11R-I	Install early fire detection in the following physical analysis units: RC-02, RC-03, RC-05, RC-04, RC-07, RC-08, RC-11, RC-14, RC-13, RC-1A	1.37E-05	1.43E-05	7.67E-6	8.11E-6	1.06

[1]The CW-02 sensitivity produces a slightly reduced benefit relative to the base case. The reduced benefit results from particular fire accident sequences in which fire-related mechanisms that cause complete failure of RCIC in the base cases are removed by the mitigation alternative. Although RCIC is not susceptible to outright failure for this mitigation alternative, the system is still susceptible to hot short induced mechanisms of failure for the sequences in question. Due to the higher hot short probabilities for the sensitivity, the delta CDF for the applicable accident sequences is smaller in the sensitivity quantification, and thus, the benefit is reduced.

NRC Request:

12. Table 2-3 notes that the "Late" time category (i.e., greater than 24 hours) is not used in PSA model Rev. 7.1. Clarify that all Level 2 sequences are mapped into "early" or "intermediate" release categories. If not, assess the impact of this incompleteness on the results of the sensitivity study.

Energy Northwest Response:

All Level 2 sequences are mapped into "early" or "intermediate" release categories. Table 2-3 Note (3) from Reference F is revised to provide this additional clarification. This table is provided in Attachment 2.

References:

A. Letter, GO2-10-011, dated January 19, 2010, WS Oxenford (Energy Northwest) to NRC, "License Renewal Application"

B. Letter dated July 1, 2010, NRC to WS Oxenford (Energy Northwest), "Request for Additional Information for the Review of the Columbia Generating Station License Renewal Application – SAMA Review," (ADAMS Accession No. ML101760421)

C. Letter, GO2-10-138, dated September 17, 2010, SK Gambhir (Energy Northwest) to NRC, "Response to Request for Additional Information License Renewal Application"

D. Letter dated November 10, 2010, NRC to SK Gambhir (Energy Northwest), "Request for Additional Information for the Review of the Columbia Generating Station License Renewal Application – SAMA Review," (ADAMS Accession No. ML102870984)

E. Letter dated December 2, 2010, NRC to SK Gambhir (Energy Northwest), "Request for Additional Information for the Review of the Columbia Generating Station License Renewal Application – SAMA Review," (ADAMS Accession No. ML103330246)

F. Letter, GO2-11-032, dated January 28, 2011, SK Gambhir (Energy Northwest) to NRC, "Response to Request for Additional Information for the Review of the Columbia Generating Station License Renewal Application"

G. Letter dated March 10, 2011, NRC to SK Gambhir (Energy Northwest), "Request for Additional Information for the Review of the Columbia Generating Station License Renewal Application – Severe Accident Mitigation Alternative Review," (ADAMS Accession No. ML110670379)

Energy Northwest

Sensitivity Study

Based Upon the

Columbia Generating Station

Integrated Full Power Probabilistic Safety Assessment

Model Revision 7.1 dated September 2010

Revised Tables

Note: Revision bars or shading are used to indicate revisions.

Table 2-3

RELEASE SEVERITY AND TIMING CLASSIFICATION SCHEME[1]

Release Severity	
Classification Category	Cs Iodide % in Release
High (H)	Greater than 10
Medium or Moderate (M)	1 to 10
Low (L)	0.1 to 1
Low-low (LL)	Less than 0.1
No iodine (OK)	0

Release Timing	
Classification Category	Time of Initial Release[2] Relative to Time for General Emergency Declaration
Late (L)[3]	Greater than 24 hours
Intermediate (I)	3 to 24 hours
Early (E)	Less than 3 hours[4]

RADIONUCLIDE RELEASE CATEGORIES DERIVED FOR COLUMBIA GENERATING STATION

Time of Release	Magnitude of Release			
	H	M	L	LL
E	H/E	M/E	L/E	LL/E
I	H/I	M/I	L/I	LL/I
L [3]	H/L	M/L	L/L	LL/L

(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.

(3) The "Late" time category is not used for the Integrated PSA Model Rev. 7.1. All Level 2 sequences are mapped into either the "Early" or "Intermediate" release categories.

(4) Evacuation time for the Columbia EPZ is found to be less than 3 hours.

Table A-1 (Fire): Comparison CDF Contributions for PSA Models Rev. 6.2 and Rev. 7.1[2]

Fire Compartment[3]	Rev 6.2 Fire CDF (/rx-yr)	Rev. 7.1 Fire CDF (/rx-yr)	Fire CDF Difference	Percentage Increase[1]	Discussion
Total	**7.4E-06**	**1.37E-05**	**6.31E-06**	**85%**	
W07 (Radwaste 467' Division 2 Electrical Equipment)	9.0E-08	1.7E-06	1.6E-06	21%	The Rev. 7.1 FPSA modeling of long term RCIC operation differs from the Rev. 6.2 FPSA in crediting RCS makeup in the event RCIC fails to continue to run due to containment back-pressure. The assumption that an RCS makeup source was available was not carried forward for Rev 7.1 FPSA. The Integrated PSA Model Rev. 7.1 was established for SAMA evaluations and this conservatism is judged appropriate for the SAMA application. This resulted in an increased importance for fire compartment W07.
T1C (Turbine Generator East 441')	5.2E-08	1.3E-06	1.3E-06	17%	Based on the revised Rev. 7.1 RFW fault tree model, RFW is now failed if a full compartment burnout occurs. Modeling of additional dependencies in the Rev 7.1 Internal Events model identified increased importance to this fire compartment.
W04 (Radwaste 467' Division 1 Electrical Equipment Room)	8.4E-07	1.7E-06	8.6E-07	12%	Rev. 7.1 has a conservatism in modeling the failure of some Division 2 equipment associated with this fire compartment. The investigation into this conservatism was not completed prior to performing the sensitivity study. When this conservatism is removed, the Rev. 7.1 W04 compartment fire CDF decreases by a factor of about two. Overall fire CDF decreases by about 6%. This modeling would not adversely affect the SAMA analysis results by screening out a cost-beneficial SAMA candidate.
W08 (Radwaste 467' Switchgear Room #2)	3.6E-07	9.7E-07	6.1E-07	8%	See discussion for compartment W07.

Table A-1 (Fire): Comparison CDF Contributions for PSA Models Rev. 6.2 and Rev. 7.1[2]

Fire Compartment[3]	Rev 6.2 Fire CDF (/rx-yr)	Rev. 7.1 Fire CDF (/rx-yr)	Fire CDF Difference	Percentage Increase[1]	Discussion
Total	**7.4E-06**	**1.37E-05**	**6.31E-06**	**85%**	
W03 (Radwaste 467'-525' Cable Chase)	4.5E-07	9.4E-07	5.0E-07	7%	The Rev. 6.2 FPSA credits one train of RHR to be available and not failed for a fire in this compartment. This was not carried forward to the Rev. 7.1 integrated model. The investigation to confirm this modeling assumption was not completed prior to performing the sensitivity study. When this conservatism is removed, the Rev. 7.1 W03 compartment fire CDF decreases by a factor of about two. Overall fire CDF decreases by about 3%. This modeling would not adversely affect the SAMA analysis results by screening out a cost-beneficial SAMA candidate.
W14 (Radwaste 467' Switchgear Room #1)	1.0E-06	1.4E-06	4.5E-07	6%	The Rev. 6.2 FPSA model provided non-repair probabilities to recover fire-induced losses of offsite power. This assumption was removed for Rev 7.1 integrated FPSA. This resulted in an increase in risk importance in the Rev 7.1 model for this compartment.
R1C (Southeast Reactor Building 471')	2.0E-08	3.9E-07	3.7E-07	5%	Increased CDF in Rev. 7.1 for reasons similar to compartment R1K.
W1A (Radwaste Building 437')	1.2E-07	4.4E-07	3.2E-07	4.3%	See discussion for compartment W07.
W13 (Radwaste 525' Emergency Chiller)	2.0E-07	4.9E-07	2.9E-07	3.9%	See discussion for compartment W07.
R1L (Reactor Building 572')	3.3E-09	2.4E-07	2.3E-07	3.2%	See discussion for compartment W07.
W02 (Cable Spreading Room)	2.2E-07	4.4E-07	2.2E-07	2.9%	For one fire scenario modeled for W02, RHR is modeled as completely failed due to fire impacts. This is conservative. See the discussion for compartment W03.
T1A (Turbine Generator West 441')	1.6E-07	2.9E-07	1.3E-07	1.7%	See discussion for compartment W07.
T1D (Turbine Generator West 471')	4.9E-08	1.6E-07	1.1E-07	1.4%	See discussion for compartment W07.

Table A-1 (Fire): Comparison CDF Contributions for PSA Models Rev. 6.2 and Rev. 7.1[2]

Fire Compartment[3]	Rev 6.2 Fire CDF (/rx-yr)	Rev. 7.1 Fire CDF (/rx-yr)	Fire CDF Difference	Percentage Increase[1]	Discussion
Total	**7.4E-06**	**1.37E-05**	**6.31E-06**	**85%**	
T1H (Turbine Generator Center 501')	3.5E-09	1.1E-07	1.0E-07	1.4%	See discussion for compartment W07.
R1B (Northeast Reactor Building 471')	5.8E-08	1.6E-07	1.0E-07	1.4%	This was a methodology change for Rev. 7.1. A 0.5 recovery probability was applied in Rev. 6.2 to re-close RHR-V-27A if it spuriously opens due to fire. RG 1.200 requires that analysis be performed to demonstrate that RHR-V-27A would not be damaged by the hot short by bypass of torque limit switch. The 0.5 credit was removed for Rev. 7.1.
T10 (West Transformer Vault)	1.9E-09	8.6E-08	8.4E-08	1.1%	See discussion for compartment T1C.
T1I (Turbine Generator East 501')	3.0E-09	8.4E-08	8.1E-08	1.1%	See discussion for compartment W07.
T1G (Turbine Generator West 501')	9.4E-09	8.7E-08	7.7E-08	1.0%	See discussion for compartment W07.
W05 (Radwaste 467' Battery Room 1)	2.5E-07	3.2E-07	6.4E-08	0.9%	A human failure event for aligning SW as an alternate injection source was added to the modeling in Rev. 7.1.
R1K	2.0E-08	6.9E-08	4.9E-08	0.7%	A model linking problem in Rev 6.2 was corrected and incorporated into Rev 7.1. This produced a small increase in the compartment risk importance.
S01	2.6E-09	4.6E-08	4.3E-08	0.6%	See discussion for compartment W07.
R1E	6.5E-10	4.1E-08	4.0E-08	0.5%	See discussion for compartment R1K.

[1] Computed for each compartment by dividing CDF Difference for each compartment by the total Rev. 6.2 Fire CDF.
[2] This table compares CDF for all fire compartments whose Rev. 7.1 CDF increased by at least 1% from the Rev. 6.2 Fire compartment CDF.

Table A-1 (Fire): Comparison CDF Contributions for PSA Models Rev. 6.2 and Rev. 7.1[2]

Footnotes (cont'd):

[3] The table below cross-references the fire compartment labels listed in Table A-1 (Fire) with those in Table E.3-7 of the ER.

Table A-1 (Fire)	Table E.3-7 of the ER
W07	RC-07
T1C	TG-1C
W04	RC-04
W08	RC-08
W03	RC-3
W14	RC-14
R1C	R-1C
W1A	RC-1A
W13	RC-13
R1L	Not in table
W02	RC-2
T1A	TG-1A
T1D	TG-1D
T1H	Not in table
R1B	R-1B
T10	Not in table
T1I	Not in table
T1G	Not in table
W05	RC-5
R1K	Not in table
S01	Not in table
R1E	Not in table

Table A-3: Internal Events Level 2 Release Categories

Release Category	Description	Frequency (per year)	Percentage
OK	Containment Intact	1.88E-06	25.1%
H/E	High/Early (LERF-BOC)	3.66E-07	4.9%
H/I	High/Intermediate	2.35E-07	3.1%
M/E	Moderate/Early	2.19E-07	2.9%
M/I	Moderate/Intermediate	4.07E-06	54.5%
L/E	Low/Early	2.30E-08	0.3%
L/I	Low/Intermediate	3.86E-09	0.1%
LL/E	Low Low/Early	1.64E-07	2.2%
LL/I	Low Low/Intermediate	5.33E-07	7.1%
	Total	7.50E-06[1]	100%

[1]This sum of the release category frequencies differs slightly from the total Internal Events CDF reported in Table A-1 (Internal Events). The value in Table A-1 (Internal Events) is lower due to cutset minimalization that is performed during the PSA quantification.

Table A-4: Fire Level 2 Release Categories

Release Category	Description	Frequency (per year)	Percentage
OK	Containment Intact	3.53E-06	25.7%
H/E	High/Early (LERF-BOC)	4.35E-08[1]	0.3%
H/I	High/Intermediate	7.93E-08	0.6%
M/E	Moderate/Early	1.77E-08	0.1%
M/I	Moderate/Intermediate	8.55E-06	62.3%
L/E	Low/Early	2.33E-08	0.2%
L/I	Low/Intermediate	8.49E-09	0.1%
LL/E	Low Low/Early	8.61E-07	6.3%
LL/I	Low Low/Intermediate	6.13E-07	4.5%
	Total	1.37E-05	100%

[1]The H/E release decreased from 2.46 E-07 in Rev. 6.2 (LEN) to 4.35 E-08 in Rev. 7.1 for the FPSA. The decreases for the Internal Events and Seismic hazards were of approximately the same amount but a lower percentage change primarily since the Fire Level 2 H/E frequency is dominated by Loss of RPV makeup scenarios. For the Rev 7.1 Level 2 PSA, the likelihood for Loss of RPV makeup scenarios leading to the H/E end state is much smaller than compared to the Rev 6.2 model. For example, the Rev. 7.1 Level 2 MAAP runs show that Loss of RPV makeup scenarios generally result in delayed containment failure (i.e., non-early release). For the Rev 7.1 Level 2 model, the dominant contributors to the H/E end state for Loss of RPV makeup scenarios involve failures such as Containment Isolation failure, Hydrogen Deflagration, or other phenomenological events which are low probability events.

Table A-5: Seismic Level 2 Release Categories

Release Category	Description	Frequency (per year)	Percentage
OK	Containment Intact	5.54E-07	11.4%
H/E	High/Early (LERF-BOC)	1.87E-06	38.5%
H/I	High/Intermediate	6.09E-07	12.5%
M/E	Moderate/Early	4.46E-09	0.1%
M/I	Moderate/Intermediate	1.12E-06	23.0%
L/E	Low/Early	4.90E-09	0.1%
L/I	Low/Intermediate	7.17E-10	0.0%
LL/E	Low Low/Early	1.29E-07	2.7%
LL/I	Low Low/Intermediate	5.75E-07	11.8%
	Total	4.86E-06	100%

Table A-6: Base Case Sensitivity Results for Internal Events

Release Category	Whole Body Dose (50 miles, person-rem/yr)	Economic Impact (50 miles, $/yr)
OK	1.50E-03	6.66E-02
H/E	7.36E-01	1.05E+03
H/I	3.41E-01	6.18E+02
M/E	2.06E-01	2.09E+02
M/I	4.03E+00	5.09E+03
L/E	3.13E-02	4.42E+01
L/I	3.82E-03	4.83E+00
LL/E	1.87E-02	1.57E+00
LL/I	1.24E-01	5.97E+01
TOTAL	**5.49E+00**	**7.08E+03**

Table A-7: Base Case Sensitivity Results for Fire

Release Category	Whole Body Dose (50 miles, person-rem/yr)	Economic Impact (50 miles, $/yr)
OK	2.79E-03	1.24E-01
H/E	8.74E-02	1.25E+02
H/I	1.15E-01	2.09E+02
M/E	1.67E-02	1.69E+01
M/I	8.46E+00	1.07E+04
L/E	3.17E-02	4.47E+01
L/I	8.40E-03	1.06E+01
LL/E	9.82E-02	8.26E+00
LL/I	1.42E-01	6.87E+01
TOTAL	**8.96E+00**	**1.12E+04**

Table A-16: QUALITATIVE SCREENING OF SAMA CANDIDATES (ORIGINALLY SCREENED AS CRITERION E "VERY LOW BENEFIT")

SAMA ID	Modification (Potential Enhancement)	Revised Criteria	Basis for Screening/ Modification Enhancements [1]
AC/DC-05	Provide DC bus cross-ties	D	With the ability to provide alternate AC power to the chargers for the DC buses from DG-3 or DG-4, this SAMA candidate provides little risk reduction. The CDF and LERF RRW values associated with making the cross-ties between divisional DC power sources always available are 1.021 and 1.0002, respectively (affects all hazards, but primarily Fire), and the estimated uncertainty benefit based on RRW is approximately $180,000. This benefit represents two cross-ties: one between Division 1 and 2 and the other between Division 1 or 2 to Division 3. Note: Division 3 is not of sufficient size to backfeed Division 1 or 2 loads. The implementation cost estimate is $1,590,000 and includes design, license amendment, materials, installation, testing and training. With the significant difference in estimated RRW uncertainty benefit and the implementation cost, the screening criterion for this SAMA candidate is changed to D – Excessive Implementation Cost. This SAMA candidate is not considered for further evaluation.
AC/DC-06	Provide additional DC power to the 120/240V vital AC system	E	120/240V AC is not risk significant at CGS. The CDF and LERF RRW values associated with making the buses perfect are 1.002 and 1.000, respectively (affects primarily Fire). The estimated uncertainty benefit based on RRW is less than $15,000, which is below the cost for a small design change at CGS. Therefore, this SAMA candidate is determined to have a very low benefit and is not considered for further evaluation.
AC/DC-08	Increase training on a response to a loss of two 120V AC buses that cause inadvertent actuation signals	E	120/240V AC is not risk significant at CGS. The estimated uncertainty benefit based on RRW associated with AC/DC-06 provides a very small benefit when making the120V AC sources perfect. Abnormal procedures currently exist at CGS for loss of 120V AC, which contain detailed information on lost indication and specific restoration actions. The operators receive periodic operator training on these procedures. Improving operator response associated with the loss of a 120V AC bus would not be likely to yield a SAMA candidate with real benefit. Therefore, this SAMA candidate is determined to have a very low benefit and will not be considered for further evaluation.

[1] See Reference F for Note 1

Table A-16: QUALITATIVE SCREENING OF SAMA CANDIDATES (ORIGINALLY SCREENED AS CRITERION E "VERY LOW BENEFIT")

SAMA ID	Modification (Potential Enhancement)	Revised Criteria	Basis for Screening/ Modification Enhancements [1]
AC/DC-21	Use fire water system as a backup source for diesel cooling	E	The DG cooling water source is SW. This SAMA candidate only addresses loss of SW to the DG and not to other equipment (since this SAMA candidate is attempting to increase DG availability.) The CDF and LERF RRW values associated with doubling the DG cooling reliability are 1.005 and 1.000, respectively (affects primarily Fire). The estimated uncertainty benefit based on RRW is less than $70,000, which is below the cost for a small design change at CGS. Therefore, this SAMA candidate is not considered for further evaluation.
AC/DC-22	Add a new backup source of diesel cooling	E	This SAMA candidate is similar in intent to AC/DC-21. The RRW associated with doubling the DG cooling reliability calculated for AC/DC-21 also applies to this SAMA candidate, and the estimated uncertainty benefit is below the cost for a small design change at CGS. Therefore, this SAMA candidate is not considered for further evaluation.
AT-04	Increase boron concentration in the SLC system	B	A change to the CGS Technical Specifications has been submitted to the NRC for increasing the SLC boron concentration (i.e., use of boron enriched in the isotope B-10). This TS change achieves the intent of this SAMA candidate. Therefore, the screening criterion for this SAMA candidate is changed to Criterion B – Already Implemented.
CB-02	Add redundant and diverse limit switches on each CIV	D	Isolation at CGS is considered quite reliable. CGS CIVs that only provide a containment isolation function (V-Sequence related) are air-operated. The CDF and LERF RRW values associated with eliminating containment isolation failures (except pre-existing and flooding) and reducing ISLOCA failures by one half are 1.002 and 1.018, respectively (primarily Internal Events LERF), and the estimated uncertainty benefit based on RRW is approximately $260,000. The implementation cost estimate is $1,759,000 and includes design, materials, installation, testing and training for 21 motor-operated valves (MOVs) in containment isolation groups 5, 6 and 7 and emergency core cooling system (ECCS) and reactor core isolation and cooling (RCIC) system MOVs that close on system auto-start. With the significant difference in estimated RRW uncertainty benefit and the implementation cost, the screening criterion for this SAMA candidate is changed to D – Excessive Implementation Cost.

Table A-16: QUALITATIVE SCREENING OF SAMA CANDIDATES (ORIGINALLY SCREENED AS CRITERION E "VERY LOW BENEFIT")

SAMA ID	Modification (Potential Enhancement)	Revised Criteria	Basis for Screening/ Modification Enhancements [1]
CB-05	Install self-actuating CIVs	D	Containment isolation at CGS is considered very reliable. CGS CIVs that are normally open and have a containment isolation function are air-operated and are self-actuating. The estimated uncertainty benefit based on RRW that was calculated for SAMA candidate CB-02 ($260,000) also applies to this SAMA candidate. The implementation cost estimate is $6,179,000 and includes design, license amendment, materials, installation, testing and training for converting 21 MOVs to fail-safe air operators in containment isolation groups 5, 6, and 7 and ECCS and RCIC MOVs that close on system auto-start. With the significant difference in estimated RRW uncertainty benefit and the implementation cost, the screening criterion for this SAMA candidate is changed to D – Excessive Implementation Cost. Therefore, this SAMA candidate is not considered for further evaluation.
CC-08	Modify ADS components to improve reliability	E	The ADS at CGS is very reliable and not risk significant. The CDF and LERF RRW values associated with doubling the ADS valves' reliability are calculated to both be 1.000, indicating no risk improvement, and the estimated uncertainty benefit is well below the cost for a small design change at CGS. Therefore, this SAMA candidate is not considered for further evaluation.
CC-09	Add signals to open SRVs automatically in an MSIV closure transient	E	For an MSIV closure event, one or more SRVs may open briefly. Opening of SRVs is very reliable and not a significant contributor to risk. The CDF and LERF RRW values associated with making the SRV pressure relief function perfect are 1.0041 and 1.000, respectively (affects Internal Events only), and the estimated uncertainty benefit based on RRW is less than $10,000, which is well below the cost for a small design change at CGS. Therefore, this SAMA candidate is not considered for further evaluation.

Table A-16: QUALITATIVE SCREENING OF SAMA CANDIDATES (ORIGINALLY SCREENED AS CRITERION E "VERY LOW BENEFIT")

SAMA ID	Modification (Potential Enhancement)	Revised Criteria	Basis for Screening/ Modification Enhancements [1]
CC-12	Add a diverse low pressure injection system	D	CGS has significant redundancy of low pressure systems; thus these systems have low to moderate risk significance. The CDF and LERF RRW values associated with reducing the unavailability of the low pressure ECCS injection function by 3 orders of magnitude are 1.046 and 1.007, respectively (affects Internal Events and Fire), and the estimated uncertainty benefit based on RRW is approximately $1,000,000. The implementation cost for this SAMA was evaluated by Vermont Yankee to be greater than $3,900,000. With the significant difference in estimated RRW uncertainty benefit and the implementation cost, the screening criterion for this SAMA candidate is changed to D – Excessive Implementation Cost. This SAMA candidate is not considered for further evaluation.
CC-13	Increase flowrate of suppression pool cooling	D	The increase in flowrate for CGS adds little benefit. Cooling is provided by RHR Trains A and B. Once SPC is activated, additional cooling will not provide additional mitigating benefit. Significant time currently exists for this operator action. However, a potential benefit to ATWS sequences is to provide additional operator time to place SLC in service. The CDF and LERF RRW values associated with making the operator action perfect for initiating SLC during an MSIV closure ATWS are 1.001 and 1.007, respectively. The estimated uncertainty benefit based on RRW is approximately $110,000. Modification of both RHR Trains A and B pump impellers, increasing the horsepower of the pump motors and redesigning the distribution system would be required to achieve this benefit. The estimated implementation cost for this SAMA candidate is $3,230,000. With the significant difference in estimated RRW uncertainty benefit and the implementation cost, the screening criterion for this SAMA candidate is changed to D – Excessive Implementation Cost. Therefore, this SAMA candidate is not considered for further evaluation.

Table A-16: QUALITATIVE SCREENING OF SAMA CANDIDATES (ORIGINALLY SCREENED AS CRITERION E "VERY LOW BENEFIT")

SAMA ID	Modification (Potential Enhancement)	Revised Criteria	Basis for Screening/ Modification Enhancements [1]
FR-01	Replace mercury switches in FP system	B	The original diesel fire pump controllers were designed with mercury switches. The diesel fire pump controllers have been evaluated and are approved as part of the CGS obsolescence program. One diesel fire pump controller remains to be replaced as part of this existing program. Therefore, the screening criterion for this SAMA candidate is changed to Criterion B – Already Implemented. This SAMA candidate is not considered for further evaluation.
FR-02	Upgrade fire compartment barriers	D	The CGS IPEEE conclusions cited no weaknesses in compartment fire barriers that contributed to any significant risk. A potential SAMA candidate associated with providing fire barriers for the two oil-filled transformers in each of the critical switchgear rooms was identified. The barriers would be required to be sufficiently rugged or a suppression system sufficiently fast acting to contain the potentially explosive transformer fire. Although a portion of the 480V distribution would be lost due to the transformer failure, the protected switchgear, the other 480V oil-filled transformer, and other components in the division would still receive power. Special HVAC cooling and ducting is also required to preserve the effectiveness of the fire barrier and to provide adequate transformer cooling. This SAMA candidate was modeled by setting the accident sequences involving ignition of oil-filled transformer fires in switchgear rooms to zero. The CDF and LERF RRW values for addition of four fire barriers to separate each of the oil filed transformers from the switchgear, inverter, and other electrical panels in both the Division 1 and Division 2 electrical switchgear rooms are 1.034 and 1.0003, respectively (affects Fire only). The estimated implementation cost for this SAMA candidate is $3,300,000. With the significant difference in estimated RRW uncertainty benefit and the implementation cost, the screening criterion for this SAMA candidate is changed to D – Excessive Implementation Cost. Therefore, this SAMA candidate is not considered for further evaluation.
FW-03	Install an independent diesel for the CST makeup pumps	E	CGS has the ability to connect the diesel driven fire water pump to the suction of a condensate booster pump for RPV makeup. The CDF RRW associated with making the uncertainty of one CST very low (see SAMA candidate CP-08) is 1.001 (affects Internal Events, no LERF contribution). The estimated uncertainty based on the RRW value of SAMA candidate CP-08 represents the uncertainty benefit expected of this SAMA candidate and is well below the cost for a small design change at CGS. Therefore, this SAMA candidate is not considered for further evaluation.

Table B-1: Summary of PSA Cases[1]

SAMA Candidate	Description	Model Approach	Risk Reduction CDF (1/yr)			Total CDF (1/yr)
			Internal	Fire	Seismic	
AC/DC-30R	SAMA candidate AC/DC-10 "provide an additional diesel generator" address DG-1 unavailability. Since DG-2 is more important to fire risk, an additional SAMA candidate to examine risk improvement for DG-2 will be considered.	This SAMA candidate adds an additional diesel generator that could be aligned to either 4.16 KV bus SM-7 or SM-8. The diesel generator would differ in design from DG-1 and DG-2 to minimize the likelihood of diesel generator CCF events. The PSA was modified to make DG-2 perfectly reliable to start and run (a different case, AC/DC-10, examined risk benefit from making DG-1 perfectly reliable). To accomplish this, gate G2AC544 was set to a low value. Additionally, any loss of DG-1 and DG-2 was transferred to the SBO event trees, as this is the definition of SBO at CGS, and produces realistic modeling for this SAMA candidate.	7.46E-06	1.16E-05	4.75E-06	2.38E-05
CC-26R	Install hard pipe from diesel fire pump to vessel.	The existing method of providing the fire water injection includes hookup of hoses from the FP system to the condensate system. By eliminating human errors in the model, the hard pipe system effectiveness can be simulated. Set to zero the human failure events for alignment of diesel fire pump to vessel. To accomplish this, set the following HEPs to zero: FP-HUMN-SBOLH3LL FP-HUMNSYS62H3LL	7.48E-06	1.37E-05	4.86E-06	2.60E-05

Table B-2: Internal Events Benefit Results for Analysis Cases

Case	Case 45 (AC/DC-30R)	Case 46 (CC-26R)	Case 47 (OT-10R)	Case 48 (FW-04)	Case 49 (CB-10R)	Case 09 (CB-08)
Off-site Annual Dose (rem)	5.48E+00	5.48E+00	5.50E+00	3.20E+00	5.39E+00	5.35E+00
Off-site Annual Property Loss ($)	$7,068	$7,062	$7,087	$4,213	$6,947	$6,881
Comparison CDF	7.50E-06	7.50E-06	7.50E-06	7.50E-06	7.50E-06	7.50E-06
Comparison Dose (rem)	5.49E+00	5.49E+00	5.49E+00	5.49E+00	5.49E+00	5.49E+00
Comparison Cost ($)	$7,079	$7,079	$7,079	$7,079	$7,079	$7,079
Enhanced CDF	7.46E-06	7.48E-06	7.51E-06	4.50E-06	7.34E-06	7.39E-06
Reduction in CDF	**0.53%**	**0.27%**	**0.13%**	**40.00%**	**2.13%**	**1.47%**
Reduction in Off-site Dose	**0.18%**	**0.18%**	**0.18%**	**41.71%**	**1.82%**	**2.55%**
Immediate Dose Savings (On-site)	$3	$2	$1	$258	$14	$9
Long Term Dose Savings (On-site)	$15	$8	$4	$1,126	$60	$41
Total Accident Related Occupational Exposure **(AOE)**	$18	$9	$5	$1,385	$74	$51
Cleanup/Decontamination Savings (On-site)	$563	$282	$141	$42,233	$2,252	$1,549
Replacement Power Savings (On-site)	$831	$415	$208	$62,293	$3,322	$2,284
Averted Costs of On-site Property Damage **(AOSC)**	$1,394	$697	$348	$104,526	$5,575	$3,833
Total On-site Benefit	**$1,412**	**$706**	**$353**	**$105,911**	**$5,649**	**$3,883**
Averted Public Exposure **(APE)**	$261	$261	$261	$59,769	$2,610	$3,654
Averted Off-site Damage Savings **(AOC)**	$144	$222	$104	$37,401	$1,723	$2,584
Total Off-site Benefit	**$405**	**$483**	**$365**	**$97,170**	**$4,333**	**$6,238**
Total Benefit (On-site + Off-site)	**$1,817**	**$1,189**	**$718**	**$203,081**	**$9,981**	**$10,121**

Table B-3: Fire Benefit Results for Analysis Cases

Case	Case 45 (AC/DC-30R)	Case 46 (CC-26R)	Case 47 (OT-10R)	Case 48 (FW-04)	Case 49 (CB-10R)	Case 09 (CB-08)
Off-site Annual Dose (rem)	7.92E+00	8.88E+00	8.96E+00	6.64E+00	8.96E+00	8.96E+00
Off-site Annual Property Loss ($)	$9,857	$11,070	$11,170	$8,262	$11,168	$11,168
Comparison CDF	1.37E-05	1.37E-05	1.37E-05	1.37E-05	1.37E-05	1.37E-05
Comparison Dose (rem)	8.96E+00	8.96E+00	8.96E+00	8.96E+00	8.96E+00	8.96E+00
Comparison Cost ($)	$11,168	$11,168	$11,168	$11,168	$11,168	$11,168
Enhanced CDF	1.16E-05	1.37E-05	1.37E-05	1.03E-05	1.37E-05	1.37E-05
Reduction in CDF	**15.33%**	**0.00%**	**0.00%**	**24.82%**	**0.00%**	**0.00%**
Reduction in Off-site Dose	**11.61%**	**0.89%**	**0.00%**	**25.89%**	**0.00%**	**0.00%**
Immediate Dose Savings (On-site)	$181	$0	$0	$293	$0	$0
Long Term Dose Savings (On-site)	$788	$0	$0	$1,276	$0	$0
Total Accident Related Occupational Exposure **(AOE)**	$969	$0	$0	$1,569	$0	$0
Cleanup/Decontamination Savings (On-site)	$29,563	$0	$0	$47,864	$0	$0
Replacement Power Savings (On-site)	$43,605	$0	$0	$70,599	$0	$0
Averted Costs of On-site Property Damage **(AOSC)**	$73,168	$0	$0	$118,463	$0	$0
Total On-site Benefit	**$74,137**	**$0**	**$0**	**$120,032**	**$0**	**$0**
Averted Public Exposure **(APE)**	$27,144	$2,088	$0	$60,552	$0	$0
Averted Off-site Damage Savings **(AOC)**	$17,109	$1,279	$26	$37,923	$0	$0
Total Off-site Benefit	**$44,253**	**$3,367**	**$26**	**$98,475**	**$0**	**$0**
Total Benefit (On-site + Off-site)	**$118,390**	**$3,367**	**$26**	**$218,507**	**$0**	**$0**

Table B-4: Seismic Benefit Results for Analysis Cases

Case	Case 45 (AC/DC-30R)	Case 46 (CC-26R)	Case 47 (OT-10R)	Case 48 (FW-04)	Case 49 (CB-10R)	Case 09 (CB-08)
Off-site Annual Dose (rem)	5.77E+00	5.91E+00	5.91E+00	5.91E+00	5.91E+00	5.91E+00
Off-site Annual Property Loss ($)	$8,241	$8,444	$8,444	$8,444	$8,444	$8,444
Comparison CDF	4.86E-06	4.86E-06	4.86E-06	4.86E-06	4.86E-06	4.86E-06
Comparison Dose (rem)	5.91E+00	5.91E+00	5.91E+00	5.91E+00	5.91E+00	5.91E+00
Comparison Cost ($)	$8,444	$8,444	$8,444	$8,444	$8,444	$8,444
Enhanced CDF	4.75E-06	4.86E-06	4.86E-06	4.86E-06	4.86E-06	4.86E-06
Reduction in CDF	**2.26%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Reduction in Off-site Dose	**2.37%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Immediate Dose Savings (On-site)	$9	$0	$0	$0	$0	$0
Long Term Dose Savings (On-site)	$41	$0	$0	$0	$0	$0
Total Accident Related Occupational Exposure **(AOE)**	$51	$0	$0	$0	$0	$0
Cleanup/Decontamination Savings (On-site)	$1,549	$0	$0	$0	$0	$0
Replacement Power Savings (On-site)	$2,284	$0	$0	$0	$0	$0
Averted Costs of On-site Property Damage **(AOSC)**	$3,833	$0	$0	$0	$0	$0
Total On-site Benefit	**$3,883**	**$0**	**$0**	**$0**	**$0**	**$0**
Averted Public Exposure **(APE)**	$3,654	$0	$0	$0	$0	$0
Averted Off-site Damage Savings **(AOC)**	$2,649	$0	$0	$0	$0	$0
Total Off-site Benefit	**$6,303**	**$0**	**$0**	**$0**	**$0**	**$0**
Total Benefit (On-site + Off-site)	**$10,187**	**$0**	**$0**	**$0**	**$0**	**$0**

Table B-5: Total Benefit Results for Analysis Cases

	Case 37 (FR-09R)	Case 38 (FR-08)	Case 39 (AT-15R)	Case 40 (OT-09R)	Case 41 (FR-12R)	Case 42 (FR-11R)	Case 43 (FR-10R)	Case 44 (FL-07R)
Internal Events	$0	$0	$39,864	$21,473	$0	$0	$0	$5,403
Fire	$101,294	$512,974	$0	$87,797	$105,130	$508,730	$13,742	$0
Seismic	$0	$0	$0	$0	$0	$0	$0	$0
Other	$0	$0	$39,864	$21,473	$0	$0	$0	$5,403
Total Benefit	$101,294	$512,974	$79,728	$130,744	$105,130	$508,730	$13,742	$10,805

	Case 45 (AC/DC-30R)	Case 46 (CC-26R)	Case 47 (OT-10R)	Case 48 (FW-04)	Case 49 (CB-10R)	Case 09 (CB-08)	Case 09 (CB-09)
Internal Events	$1,817	$1,189	$718	$203,081	$9,981	$10,121	$10,121
Fire	$118,390	$3,367	$26	$218,507	$0	$0	$0
Seismic	$10,187	$0	$0	$0	$0	$0	$0
Other	$1,817	$1,189	$718	$203,081	$9,981	$10,121	$10,121
Total Benefit	$132,210	$5,745	$1,463	$624,669	$19,962	$20,243	$20,243

Table B-7: Final Results of the Cost-Benefit Evaluation

SAMD ID	Modification	Analysis Case	Estimated Benefit	Cost of Implementation	Conclusion
OT-07R	Improve procedures and operator training to identify systems and operator actions determined to be important from the PSA.	Case 35	$197,597	$40,000	Cost Effective
FW-05R	Examine the potential for operators to control RFW and avoid a reactor trip.	Case 36	$66,860	$29,000	Cost Effective
FR-09R	Install early fire detection in the following Reactor Building analysis units: R-1B, R-1D, and R-1J.	Case 37	$101,294	$680,000	Not Cost Effective
AT-15R	Install modifications to make use of HPCS more likely for ATWS.	Case 39	$79,728	$2,825,000	Not Cost Effective
OT-09R	For the non-LOCA initiating events, credit the Z (PCS recovery) function.	Case 40	$130,744	$130,000	Cost Effective
FR-12R	Install early fire detection in the following physical analysis units: T-1A, T-12, T-1C, and T-1D.	Case 41	$105,130	$725,000	Not Cost Effective
FR-11R	Install early fire detection in the following analysis units: RC-02, RC-03, RC-04, RC-05, RC-07, RC-08, RC-11, RC-13, RC-14, and RC-1A.	Case 42	$508,730	$1,035,000	Not Cost Effective
FR-10R	Install early fire detection in the Main Control Room: RC-10.	Case 43	$13,742	$535,000	Not Cost Effective
FL-07R	Protect the HPCS from flooding resulting from ISLOCA events.	Case 44	$10,805	$1,050,000	Not Cost Effective
AC/DC-30R	Provide an additional DG diverse from DG-1 and DG-2.	Case 45	$132,210	$10,000,000	Not Cost Effective
CC-26R	Install hard pipe from diesel fire pump to vessel.	Case 46	$5,745	$710,000	Not Cost Effective
OT-10R	Increase fire pump house building integrity to withstand higher winds so the fire system will be capable of withstanding a severe weather event.	Case 47	$1,463	$735,000	Not Cost Effective
FW-04	Add a motor-driven feedwater pump.	Case 48	$624,669	$10,000,000	Not Cost Effective
CB-10R	Provide additional NDE and inspections of MS pipe in Turbine Building.	Case 49	$19,962	$125,000	Not Cost Effective

Table B-8: Final Results of the Sensitivity Cases

SAMA ID	Sensitivity Case #1[1]	Sensitivity Case #2	Estimated Cost (2008/2010)	Conclusion
FL-04R	$390,642	$615,345	$377,000	Cost Effective–Sensitivity Cases 1 & 2
FL-06R	$197,662	$311,465	$13,500	Cost Effective
CC-24R	$244,548	$421,991	$105,000	Cost Effective
CC-25R	$16,457	$28,919	$13,000	Cost Effective – Sensitivity Cases 1 & 2
OT-07R	$264,720	$479,509	$40,000	Cost Effective
FW-05R	$99,445	$181,382	$29,000	Cost Effective
FR-09R	$138,485	$263,365	$680,000	Not Cost Effective
AT-15R	$101,544	$191,348	$2,825,000	Not Cost Effective
OT-09R	$193,609	$331,346	$130,000	Cost Effective
FR-12R	$150,512	$273,337	$725,000	Not Cost Effective
FR-11R	$736,493	$1,322,699	$1,035,000	Cost Effective – Sensitivity Case 2
FR-10R	$19,989	$35,730	$535,000	Not Cost Effective
FL-07R	$17,942	$25,933	$1,050,000	Not Cost Effective
AC/DC-30R	$187,130	$347,093	$10,000,000	Not Cost Effective
CC-26R	$8,973	$14,461	$710,000	Not Cost Effective
OT-10R	$2,146	$3,516	$735,000	Not Cost Effective
FW-04	$904,245	$1,542,907	$10,000,000	Not Cost Effective
CB-10R	$28,619	$47,910	$125,000	Not Cost Effective

[1] The replacement power component for Sensitivity Case 1 (3% Discount Rate) is calculated using the replacement power net present value for a 1% and 5% discount rate and interpolating for the 3% discount rate.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION RELATED TO THE REVIEW OF THE SEVERE ACCIDENT MITIGATION ALTERNATIVE ANALYSIS

Enclosure 1

Amendment 34 to the LRA

Table E.10-1 Qualitative Screening of SAMA Candidates (continued)

SAMA ID	Modification (Potential Enhancement)	Screening Criterion	Basis for Screening/ Modification Enhancements	Source
CC-18	Revise procedure to allow use of suppression pool jockey pump for injection.	Criterion A Not Applicable	CGS does not have a suppression pool jockey pump. Therefore, the intent of the SAMA is not applicable to CGS.	[**38**, Section 6]
CC-19	Revise procedure to re-open MSIVs.	Criterion B Already Implemented at CGS	Re-opening of MSIV's in non-LOCA events is addressed per procedures. Therefore, the intent of the SAMA has already been implemented at CGS.	[**90**], [**98**]
CC-20	Improve ECCS suction strainers or replace insulation in containment.	Criterion C Considered for Further Evaluation	Considered for final cost-benefit evaluation. Enhancements have already been made to the strainers. The existing strainers are as large as possible based on downcomer clearing loads and in the suppression pool. Therefore, improvements to the strainers will not be considered. Replacing the existing insulation within the containment could reduce the likelihood of strainer clogging. This will be considered for a final cost-benefit evaluation. Model Change – ECCS suction strainer plugging was set to zero.	
CC-21	Revise procedure to align LPCI or core spray to CST on loss of suppression pool cooling.	Criterion ~~C~~ B ~~Considered for Further Evaluation~~ Already Implemented at CGS	~~Considered for final cost-benefit evaluation. This SAMA would allow continued injection following loss of suppression pool cooling scenarios.~~ ~~Model Change – Model suppression pool cooling to be perfectly reliable~~. Providing alternate sources of injection through multiple/diverse pathways is addressed per procedures. Therefore, the intent of the SAMA has already been implemented at CGS.	