Attachment E

Severe Accident Mitigation Alternatives Analysis

Attachment E contains the following sections.

E.1 – Evaluation of GGNS PSA Model

E.2 – Evaluation of GGNS SAMA Candidates

TABLE OF CONTENTS

E.1 EVALUATION OF PROBABILISTIC SAFETY ANALYSIS MODEL E.1-1

E.1.1 PSA Model – Level 1 Analysis E.1-1

E.1.2 PSA Model – Level 2 Analysis E.1-23

E.1.2.1 Containment Performance Analysis E.1-23
E.1.2.2 Radionuclide Analysis E.1-48
E.1.2.2.1 Introduction E.1-48
E.1.2.2.2 Timing of Release E.1-48
E.1.2.2.3 Magnitude of Release E.1-48
E.1.2.2.4 Release Category Bin Assignments E.1-49
E.1.2.2.5 Mapping of Level 1 Results into the Various Release Categories E.1-50
E.1.2.2.6 Process Used to Group the Source Terms E.1-54
E.1.2.2.7 Consequence Analysis Source Terms E.1-56
E.1.2.2.8 Release Magnitude Calculations E.1-56

E.1.3 IPEEE Analysis. E.1-59

E.1.3.1 Seismic Analysis E.1-59
E.1.3.2 Fire Analysis. E.1-59
E.1.3.3 Other External Hazards E.1-67

E.1.4 PSA Model Revisions and Peer Review Summary E.1-68

E.1.4.1 Major Differences between the 1997(R1) PSA Model and the IPE Model E.1-68
E.1.4.2 Major Differences between the 2002 (R2) PSA Model and the 1997(R1) PSA Model E.1-68
E.1.4.3 Major Differences between the 2010 (R3) PSA Model and the 2002 (R2) PSA Model E.1-69
E.1.4.4 Major Differences between the 2010 (EPU) PSA Model and the 2010 (R3) PSA Model E.1-69
E.1.4.5 PSA Model Peer Review E.1-71

E.1.5 The MACCS2 Model—Level 3 Analysis E.1-71

E.1.5.1 Introduction E.1-71
E.1.5.2 Input E.1-72
E.1.5.2.1 Projected Total Population by Spatial Element. E.1-72
E.1.5.2.2 Land Fraction E.1-74
E.1.5.2.3 Watershed Class E.1-74
E.1.5.2.4 Regional Economic Data E.1-74
E.1.5.2.5 Agriculture Data E.1-75
E.1.5.2.6 Meteorological Data E.1-75
E.1.5.2.7 Emergency Response Assumptions E.1-76
E.1.5.2.8 Core Inventory E.1-76
E.1.5.2.9 Source Terms E.1-78
E.1.5.3 RESULTS. E.1-78

E.1.6 References E.1-81

E.2 EVALUATION OF GGNS SAMA CANDIDATES E.2-1

E.2.1 SAMA List Compilation. E.2-1
E.2.2 Qualitative Screening of SAMA Candidates (Phase I) E.2-2
E.2.3 Final Screening and Cost Benefit Evaluation of SAMA Candidates (Phase II) E.2-2
E.2.4 Sensitivity Analyses E.2-15
E.2.5 References E.2-17

LIST OF TABLES

Table E.1-1
GGNS EPU Model CDF Results by Major Initiators E.1-3

Table E.1-2
Correlation of Level 1 Risk Significant Terms to Evaluated SAMAs (Based on CDF) . . E.1-5

Table E.1-3
Notation and Definitions for GGNS CET Functional Nodes Description E.1-25

Table E.1-4
Correlation of Level II Risk Significant Terms to Evaluated SAMAs (Based on Large Early Release Frequency). E.1-40

Table E.1-6
GGNS Release Categories E.1-50

Table E.1-5
Release Severity and Timing Classification Scheme Summary E.1-50

Table E.1-7
Summary of GGNS Core Damage Accident Sequences Plant Damage States E.1-52

Table E.1-8
Summary of Containment Event Tree Quantification E.1-55

Table E.1-9
GGNS Release Category Source Terms E.1-57

Table E.1-10
GGNS Fire IPEEE Results E.1-61

Table E.1-11
Estimated Population Distribution within a 50-Mile Radius E.1-73

Table E.1-12
Estimated GGNS Core Inventory (Becquerels). E.1-77

Table E.1-13
Base Case Mean PDR and OECR Values for Postulated Internal Events E.1-79

Table E.1-14
Summary of Offsite Consequence Results for Sensitivity Results E.1-80

Table E.2-1
Phase I SAMAs Related to IPE and IPEEE Insights E.2-19

Table E.2-2
Summary of Phase II SAMA Candidates Considered in Cost-Benefit Evaluation E.2-30

Table E.2-3
Sensitivity Analysis Results E.2-57

LIST OF FIGURES

Figure E.1-1
GGNS Radionuclide Release Category Summary E.1-38

Figure E.1-2
Summary of GGNS Core Damage Accident Sequences Plant Damage States E.1-39

LIST OF ACRONYMS IN ATTACHMENTS E.1 AND E.2

Acronym	Definition
AC	Alternating current
ADS	Automatic depressurization system
ASDS	Alternate shutdown system
ATWS	Anticipated transient without scram
BWR	Boiling water reactor
BWROG	Boiling Water Reactor Owners Group
CCF	Common cause failure
CCW	Component cooling water
CDF	Core damage frequency
CET	Containment event tree
CNS	Cooper Nuclear Station
CPI	Consumer Price Index
CRD	Control rod drive
CsI	Cesium iodide
CST	Condensate storage tank
DC	Direct current
DF	Decontamination factor
DG	Diesel generator
ECCS	Emergency core cooling system
EDG	Emergency diesel generator
EOP	Emergency operating procedure
EPG	Emergency procedure guidelines
EPU	Extended power uprate
EPZ	Emergency planning zone

Acronym	**Definition**
ESF	Emergency safety feature
FIVE	Fire induced vulnerability evaluation
FPS	Fire protection system
FPW	Fire protection water
FW	Feedwater
GGNS	Grand Gulf Nuclear Station
HPCI	High pressure coolant injection
HPCS	High pressure core spray
HVAC	Heating, ventilation and air conditioning
IA	Instrument air
IPE	Individual Plant Examination
IPEEE	Individual Plant Examination of External Events
ISLOCA	Interfacing systems loss of coolant accident
LERF	Large early release frequency
LOCA	Loss of coolant accident
LOSP	Loss of off-site power
LPCI	Low pressure coolant injection
LPCS	Low pressure core spray
MAAP	Modular Accident Analysis Program
MACCS2	MELCOR Accident Consequences Code System 2
MSIV	Main steam isolation valve
MST	Main steam tunnel
NRC	Nuclear Regulatory Commission
OECR	Off-site economic cost risk
OSP	Off-site power
PCPL	Primary containment pressure limit

Acronym	**Definition**
PCS	Power conversion system
PDR	Population dose risk
PDS	Plant damage state
PHV	Pump house ventilation
PRA	Probabilistic Risk Assessment
PSA	Probabilistic Safety Assessment
PSW	Plant service water
RB	Reactor building
RCIC	Reactor core isolation cooling
RCS	Reactor coolant system
RHR	Residual heat removal
RPV	Reactor pressure vessel
RRW	Risk reduction worth
SAG	Severe accident guideline
SAMA	Severe accident mitigation alternative
SBO	Station blackout
SLC	Standby liquid control
SORV	Stuck open relief valve
SPC	Suppression pool cooling
SPMU	Suppression pool makeup
SRV	Safety relief valve
SSW	Standby service water
TBCW	Turbine building cooling water
WW	Wetwell

ATTACHMENT E.1

EVALUATION OF GGNS PSA MODEL

E.1 EVALUATION OF PROBABILISTIC SAFETY ANALYSIS MODEL

The severe accident risk was estimated using the Probabilistic Safety Analysis (PSA) model and a Level 3 model developed using version 1.13.1 of the MELCOR Accident Consequences Code System version 2 (MACCS2 code). The CAFTA code was used to develop the Grand Gulf Nuclear Station (GGNS) PSA Level 1 and Level 2 models. This section provides the description of GGNS PSA levels 1, 2, and 3 analyses, Core Damage Frequency (CDF) uncertainty, Individual Plant Examination of External Events (IPEEE) analyses, and PSA model peer review.

E.1.1 PSA Model – Level 1 Analysis

The PSA model (Level 1 and Level 2) used for the Severe Accident Mitigation Alternative (SAMA) analysis was the most recent internal events risk model, reflecting the GGNS extended power uprate (EPU) configuration [E.1-18 and E.1-4]. In the EPU model, the Rev. 3 model which reflects GGNS design, component failure and unavailability data as of August 2006 was modified to reflect the EPU configuration. There have been no major plant hardware changes or procedural modifications since August 2006 that would have a significant impact on the results of the SAMA analysis. Thus, the EPU model used for the SAMA analysis is appropriate. The GGNS model adopts the small event tree / large fault tree approach and uses the CAFTA code for quantifying CDF.

The PSA model has had three major revisions since the Individual Plant Examination (IPE) due to the following.

- Equipment performance: As data collection progresses, estimated failure rates and system unavailability data change.
- Plant configuration changes: Plant configuration changes are incorporated into the PSA model.
- Modeling changes: The PSA model is refined to incorporate the latest state of knowledge and recommendations from internal and industry peer reviews.

In the EPU model, the Rev. 3 model was modified to reflect the EPU configuration. The EPU model contains the major initiators leading to core damage with baseline CDFs listed in Table E.1-1.

The GGNS L1 Model was reviewed to identify those potential risk contributors that made a significant contribution to CDF. CDF-based Risk Reduction Worth (RRW) rankings were reviewed down to 1.005. Events below this point would influence the CDF by less than 0.5 percent and are judged to be highly unlikely contributors for the identification of cost-beneficial enhancements. These basic events—including component failures, operator actions, and initiating events—were reviewed to determine if additional SAMA actions may need to be considered.

Table E.1-2 provides a correlation between the Level 1 RRW risk significant events (component failures, operator actions, and initiating events) down to 1.005 identified from the GGNS PSA model and the SAMAs evaluated in Section E.2.

Table E.1-1
GGNS EPU Model CDF Results by Major Initiators

Initiating Event Group	Total IE Group Probability	% CDF
Large Loss of Coolant Accident (LOCA)	1.45E-07	7.10
Feedwater Line Break Outside of Containment	2.76E-10	0.00
Plant Service Water (PSW) Flooding Initiator	1.00E-09	0.00
Reactor Vessel Rupture	1.00E-08	0.50
Intermediate LOCA	2.03E-08	1.00
Small LOCA	1.33E-11	0.00
Small-Small LOCA	2.47E-11	0.00
Standby Service Water (SSW) Flooding Initiator	6.55E-12	0.00
Loss of Off-Site Power Initiator	2.87E-07	14.00
Loss of 500 kV Power (Preferred)(1)	5.12E-11	0.00
Loss of Power Conversion System (PCS) Initiator	2.31E-07	11.20
Closure of Main Steam Isolation Valves (MSIVs) (Initiator)	8.81E-08	4.30
PCS Available Transient	6.32E-07	30.80
Loss of Condensate Feed Water Pumps	2.20E-07	10.70
Inadvertent Open Relief Valve	9.78E-09	0.50
Loss of Alternating Current (AC) Division 1 Initiator	1.79E-08	0.90
Loss of AC Division 2 Initiator	3.82E-08	1.90
Loss of Turbine Cooling Water (TBCW)	8.09E-09	0.40
Loss of Component Cooling Water Initiating Event	6.87E-10	0.00
Loss of Control Rod Drive (CRD)	2.20E-09	0.10

Table E.1-1 (Continued)
GGNS EPU Model CDF Results by Major Initiators

Initiating Event Group	Total IE Group Probability	% CDF
Loss of Direct Current (DC) Division 1 Initiator	2.22E-10	0.00
Loss of DC Division 2 Initiator	1.30E-10	0.00
Loss of Instrument Air	1.36E-07	6.60
Loss of PSW Initiating Event	1.50E-09	0.10
Loss of Service Transformer 11	9.20E-08	4.50
Loss of Service Transformer 21	1.09E-07	5.30
Interfacing System Loss of Coolant Accident (ISLOCA) in Shutdown Cooling Supply Header (Pen 14)	2.03E-10	0.00
Total CDF	**2.05E-06**	100.00
Total Anticipated Transient without Scram (ATWS)(2)	~ 3.08E-09	0.15
Total Station Blackout (SBO)(2) (TB)	~ 7.51E-07	36.65

1. Loss of all 500 kV lines (preferred offsite power), for which the 115 kV line is still available to power the Emergency Safety Feature (ESF) loads following manual realignment of the vital buses.
2. SBO and ATWS may occur following multiple initiators; thus their contributions to CDF are listed separately.

Table E.1-2
Correlation of Level 1 Risk Significant Terms to Evaluated SAMAs (Based on CDF)

Event Name	Probability	RRW	Event Description	Disposition
%A	3.19E-05	1.036	Large LOCA	This term represents a large LOCA. Phase II SAMA 56 for detecting LOCAs was evaluated.
%S1	4.69E-06	1.005	Intermediate LOCA	This term represents an intermediate LOCA. Phase II SAMA 57 for implementing a GRA was evaluated.
%T1	2.48E-02	1.6289	Loss of offsite power initiator	This term represents a loss of offsite power initiator. Phase II SAMAs 7, 15 and 18 for improving offsite, switchyard and transformer availability were evaluated.
%T2	1.77E-01	1.0969	Loss of PCS initiator	This term represents a loss of power conversion system initiator. Phase II SAMA 28 for improving availability and reliability of feedwater was evaluated.
%T2M	2.01E-01	1.0423	Closure of MSIVs (initiator)	This term represents an inadvertent MSIV closure initiator. Phase II SAMAs 23, 37, 49, and 53 to improve SRV and MSIV availability and reliability and to reduce initiating event frequencies by implementing generation risk assessment were evaluated.
%T3A	7.98E-01	1.2633	PCS available transient	This term represents a general initiator with PCS available. Phase II SAMA 57 for scram reduction modeling, and SAMAs 34, 35, 36, and 37 for improving instrument air reliability were evaluated.
%T3B	2.00E-01	1.0934	Loss of condensate feed water pumps	This term represents a loss of condensate feedwater pumps initiator. Phase II SAMA 28 for improving availability and reliability of feedwater was evaluated.

Table E.1-2
Correlation of Level 1 Risk Significant Terms to Evaluated SAMAs (Based on CDF)

Event Name	Probability	RRW	Event Description	Disposition
%TAC1	2.56E-03	1.0078	Loss of AC Division 1 initiator	This term represents the loss of AC Division 1 initiator. Phase II SAMAs 5 and 8 for enhancing AC system reliability or to cope with loss of offsite power and SBO events were evaluated.
%TAC2	2.56E-03	1.0191	Loss of AC Division 2 initiator	This term represents the loss of AC Division 1 initiator. Phase II SAMAs 5 and 8 for enhancing AC system reliability or to cope with loss of offsite power and SBO events were evaluated.
%TIA	3.51E-03	1.0487	Loss of instrument air	This term represents a loss of instrument air initiator. Phase II SAMAs 34, 35, 36, and 37 for improving the instrument air system were evaluated.
%TST11	9.85E-02	1.029	Loss of service transformer 11	This term represents a loss of service transformer 11. Phase II SAMA 18 for protecting transformers was evaluated.
%TST21	7.48E-02	1.0384	Loss of service transformer 21	This term represents a loss of service transformer 21. Phase II SAMA 18 for protecting transformers was evaluated.
B21-FO-HEBOTTLES	1.00E+00	1.0629	Operator fails to connect gas bottles to ADS air header	This term represents a failure to manually operate ADS when IA is lost. Phase II SAMA 36 for adding automatic nitrogen backup to ADS components was evaluated.
B21-FO-HEDEP2-I	1.00E+00	1.5587	Operator fails to manually depressurize vessel with non-ADS valves	This term represents a failure to manually operate ADS when IA is lost. Phase II SAMAs 20, 21, 22, and 28 for improving high pressure injection or ADS components were evaluated.
E12-CF-MVLPCS	5.73E-05	1.0072	Two or more LPSI and LPCS injection MOVs to open	This term represents a failure of LPCI injection valves to open. Phase II SAMA 25 for bypassing LPCI low pressure permissives was evaluated.
E12-LF-FGCS	1.00E+00	1.0637	Containment spray signal generated	This term is a flag. No SAMAs need to be aligned.

Table E.1-2
Correlation of Level 1 Risk Significant Terms to Evaluated SAMAs (Based on CDF)

Event Name	Probability	RRW	Event Description	Disposition
E12-MA-TMRHRA	8.83E-03	1.0118	RHR Train A unavailable due to maintenance	This term represents a failure of LPCI. Phase II SAMAs 24, and 25 for improving or adding low pressure injection systems were evaluated.
E12-MA-TMRHRB	5.56E-03	1.0066	RHR Train B unavailable due to maintenance	This term represents a failure of LPCI. Phase II SAMAs 24, and 25 for improving or adding low pressure injection systems were evaluated.
E22-042-H	6.40E-03	1.0377	Suppression pool suction line hardware failure (long term)	This term represents a failure of a high pressure injection. Phase II SAMAs 20, 21, 22, and 28 for improving or adding high pressure injection were evaluated.
E22-CC-MVF004-G	6.30E-03	1.0742	Normally closed motor driven valve FOO4 fails to open	This term represents a failure of a high pressure injection. Phase II SAMAs 20, 21, 22, and 28 for improving or adding high pressure injection were evaluated.
E22-CC-MVF012-G	6.30E-03	1.0742	Minimum flow valve F012-C fails to open	This term represents a failure of a high pressure injection. Phase II SAMAs 20, 21, 22, and 28 for improving or adding high pressure injection were evaluated.
E22-FS-MPC001-G	3.00E-03	1.0336	HPCS motor driven pump C001 fails to start	This term represents a failure of a high pressure injection. Phase II SAMAs 20, 21, 22, and 28 for improving or adding high pressure injection were evaluated.
E22-HW-ICHPCS-G	1.60E-03	1.0174	HPCS actuation circuit failure	This term represents a failure of a high pressure injection. Phase II SAMAs 20, 21, 22, and 28 for improving or adding high pressure injection were evaluated.
E22-HW-ICMNFLO-G	1.60E-03	1.0174	Minimum flow control circuit failure	This term represents a failure of a high pressure injection. Phase II SAMAs 20, 21, 22, and 28 for improving or adding high pressure injection were evaluated.

Table E.1-2
Correlation of Level 1 Risk Significant Terms to Evaluated SAMAs (Based on CDF)

Event Name	Probability	RRW	Event Description	Disposition
E22-MA-MAHPCS-G	6.59E-03	1.0662	HPCS unavailable due to maintenance	This term represents a failure of a high pressure injection. Phase II SAMAs 20, 21, 22, and 28 for improving or adding high pressure injection were evaluated.
E22-OO-MVF012-G	3.40E-03	1.0384	Normally open motor driven valve E22-F012 fails to close	This term represents a failure of a high pressure injection. Phase II SAMAs 20, 21, 22, and 28 for improving or adding high pressure injection were evaluated.
E51-021-H	7.99E-03	1.0127	Suppression pool suction switchover fails due to hardware (long term)	This term represents a failure of a high pressure injection. Phase II SAMAs 20, 21, 22, and 28 for improving or adding high pressure injection were evaluated.
E51-026-G	6.40E-03	1.0634	RCIC pump fails—minimum flow path fails to open	This term represents a failure of a high pressure injection. Phase II SAMAs 20, 21, 22, and 28 for improving or adding high pressure injection were evaluated.
E51-035M-G	1.27E-02	1.1348	RCIC steam supply valves fail	This term represents a failure of a high pressure injection. Phase II SAMAs 20, 21, 22, and 28 for improving or adding high pressure injection were evaluated.
E51-043-G	8.29E-03	1.0839	Lube oil cooling line hardware failure	This term represents a failure of a high pressure injection. Phase II SAMA 63 for improving RCIC reliability was evaluated.
E51-CC-MVF013A-G	6.30E-03	1.0623	Motor-operated valve F013-A fails to open	This term represents a failure of a high pressure injection. Phase II SAMAs 20, 21, 22, and 28 for improving or adding high pressure injection were evaluated.
E51-FF-FSC001-G	3.51E-03	1.0335	RCIC pump start failures	This term represents a failure of a high pressure injection. Phase II SAMAs 20, 21, 22, and 28 for improving or adding high pressure injection were evaluated.

Table E.1-2
Correlation of Level 1 Risk Significant Terms to Evaluated SAMAs (Based on CDF)

Event Name	Probability	RRW	Event Description	Disposition
E51-FO-HEF031A-G	1.00E+00	1.0063	Operator fails to open SP suction valve F031-A	This term represents a failure of a high pressure injection. Phase II SAMAs 20, 21, 22, and 28 for improving or adding high pressure injection were evaluated.
E51-FO-HETRPBYP	1.00E+00	1.0307	Human error: Failure to bypass RCIC temperature trips (EOP Attachment 3)	This term represents a failure of a high pressure injection. Phase II SAMAs 20, 21, 22, and 28 for improving or adding high pressure injection were evaluated.
E51-FR-TPC001-G	2.01E-01	1.2014	RCIC turbine-driven pump fails to run	This term represents a failure of a high pressure injection. Phase II SAMAs 20, 21, 22, and 28 for improving or adding high pressure injection were evaluated.
E51-FR-TPC18HR-G	6.71E-02	1.0586	RCIC turbine fails to run for 8 hours	This term represents a failure of a high pressure injection. Phase II SAMAs 20, 21, 22, and 28 for improving or adding high pressure injection were evaluated.
E51-HW-ICLVL8-I	1.60E-03	1.0148	Hardware failure of level 8 isolation circuitry	This term represents a failure of a high pressure injection. Phase II SAMAs 20, 21, 22, and 28 for improving or adding high pressure injection were evaluated.
E51-HW-ICSYACT-G	1.60E-03	1.0148	RCIC actuation circuitry failure	This term represents a failure of a high pressure injection. Phase II SAMAs 20, 21, 22, and 28 for improving or adding high pressure injection were evaluated.
E51-MA-TMRCIC-G	1.24E-02	1.1075	RCIC unavailable due to maintenance	This term represents a failure of a high pressure injection. Phase II SAMAs 20, 21, 22, and 28 for improving or adding high pressure injection were evaluated.
HVC-LF-FGSSWAPH	1.00E+00	1.0113	Failure of SSW A pump house ventilation	This term is a flag. No SAMAs need to be aligned.

Table E.1-2
Correlation of Level 1 Risk Significant Terms to Evaluated SAMAs (Based on CDF)

Event Name	Probability	RRW	Event Description	Disposition
L21-OP-BT-1A3-D	1.00E+00	1.0382	Battery 1A3 discharged (~ 8 hours depletion time)	This term represents battery depletion before recovery of offsite power. Phase II SAMAs 1, 2, 3, 11,12, and 15 for extending available recovery time by improving DC power were evaluated.
LOSP-EPRI	1.00E-03	1.022	Conditional LOSP after a plant trip	This term represents a transient induced loss of offsite power. Phase II SAMAs 5 and 8 for improving AC power reliability were evaluated.
M24-RP-CTFLECCS	9.38E-03	1.0714	ECCS pump failure due to containment failure	This term represents loss of ECCS equipment due to containment failure. Phase II SAMAs 20, 28, 39, 41, and 60 for adding or improving injection sources not affected by a containment failure and SAMAs 19, 46 and 47 for improving the reliability of the containment vent were evaluated.
M41-FF-MLVNTHW-Q	7.98E-03	1.0099	Hardware failure of the containment venting valves	This term represents a failure of the containment vent valves. Phase II SAMAs 38, 39, 40, 41, 42, 46 and 47 for providing better suppression pool cooling, containment spray and a passive containment vent were evaluated.
N21-FO-HELVL9-I	1.00E+00	1.0827	Human error: Failure to restart reactor feed pumps following level 9 trip	This term represents a failure of a human action to restore feedwater and manually depressurize. Phase II SAMAs 20 and 61 for improving high pressure injection capability were evaluated.
N21-FO-HEPCS-G	1.00E+00	1.1081	Human error: Failure to properly align the PCS for injection	This term represents a failure of a human action to restore feedwater and manually depressurize. Phase II SAMAs 20 and 40 for improving high pressure injection and suppression pool cooling capability were evaluated.

Table E.1-2
Correlation of Level 1 Risk Significant Terms to Evaluated SAMAs (Based on CDF)

Event Name	Probability	RRW	Event Description	Disposition
NR-ACHWR-1HRS	6.00E-01	1.011	Failure to recover AC bus failure in 1 hour	This term represents a failure to recover the AC bus. Phase II SAMAs 5, 8, 17 and 18 for protecting or providing alternate bus power supplies were evaluated.
NR-ACHWR-8HRS	1.00E-02	1.0158	Failure to recover AC bus failure in 8 hours	This term represents a failure to recover the AC bus. Phase II SAMAs 5, 8, 17 and 18 for protecting or providing alternate bus power supplies were evaluated.
NRC-DEP-RCIC	8.40E-03	1.0051	Failure to manually depressurize using RCIC	This term represents a failure of a human action to manually depressurize using RCIC. Phase II SAMA 22 increased ADS reliability was evaluated.
NRC-DG-CF1HRS	9.00E-01	1.0059	Failure to recover diesel generator common cause failure in 1 hour	This term represents a failure of a human action to recover the DG common cause failure in 1 hour. Phase II SAMAs 5 and 8 to install an additional diesel or gas turbine generator were evaluated.
NRC-DGHW10&FW	2.85E-01	1.0085	Failure to recover DG hardware failure or start FW in 10 hours	This term represents a failure of a human action to recover DG hardware failure or start FW in 10 hours. Phase II SAMAs 5 and 8 to install an additional diesel or gas turbine generator were evaluated.
NRC-DG-HW10HRS	5.00E-01	1.005	Failure to recover diesel generator hardware failure in 10 hours	This term represents a failure of a human action to recover DG hardware failure in 10 hours. Phase II SAMAs 5 and 8 to install an additional diesel or gas turbine generator were evaluated.
NRC-DG-HW1HR	9.00E-01	1.0107	Failure to recover diesel generator hardware failure in 1 hour	This term represents a failure of a human action to recover DG hardware failure in 1 hour. Phase II SAMAs 5 and 8 to install an additional diesel or gas turbine generator were evaluated.

Table E.1-2
Correlation of Level 1 Risk Significant Terms to Evaluated SAMAs (Based on CDF)

Event Name	Probability	RRW	Event Description	Disposition
NRC-DG-MA1HR	9.00E-01	1.0197	Failure to recover diesel generator from maintenance in 1 hour	This term represents a failure of a human action to recover DG hardware failure in 1 hour. Phase II SAMAs 5 and 8 to install an additional diesel or gas turbine generator were evaluated.
NRC-FO-ADSBOTTLE	1.30E-03	1.0447	Failure to connect air bottles to SRV accumulators	This term represents a failure of a human action to connect air bottles to the SRV accumulators. Phase II SAMAs 22 and 37 to add larger accumulators and improve SRV pneumatic components were evaluated.
NRC-FO-FWS8HR	1.10E-02	1.0107	Failure to align FPW for long term injection	This term represents a failure of a human action to align the firewater system for injection. Phase II SAMAs 24 and 25 for Improved low pressure injection capability were evaluated.
NRC-FO-FWSACT	5.70E-01	1.0927	Failure to align FPW for long term injection	This term represents a failure of a human action to align the firewater system for injection. Phase II SAMAs 24 and 25 for Improved low pressure injection capability were evaluated.
NRC-OSP-CNT	1.21E-02	1.0052	Fail to recover OSP given long term containment failure	This term represents a failure to recover offsite power. Phase II SAMAs 1, 2, 3, 11, 12, 14 and 15 for extending available recovery time by improving DC power were evaluated.
NRC-OSP-DLG0	1.28E-01	1.0135	Fail to recover OSP given 0 FTR * No SSW PHV failures	This term represents a failure to recover offsite power. Phase II SAMAs 1, 2, 3, 11, 12, 14 and 15 for extending available recovery time by improving DC power were evaluated.
NRC-OSP-DSG0	6.18E-01	1.3513	Fail to recover OSP given U2 * 0 FTR * No SSW PHV failures	This term represents a failure to recover offsite power. Phase II SAMAs 1, 2, 3, 11, 12, 14 and 15 for extending available recovery time by improving DC power were evaluated.
NRC-OSP-DSG0SSW0	2.62E-01	1.0058	Fail to recover OSP given U2 * 0 FTR * 1 or 2 SSW PHV FTS	This term represents a failure to recover offsite power. Phase II SAMAs 1, 2, 3, 11, 12, 14 and 15 for extending available recovery time by improving DC power were evaluated.

Table E.1-2
Correlation of Level 1 Risk Significant Terms to Evaluated SAMAs (Based on CDF)

Event Name	Probability	RRW	Event Description	Disposition
NRC-OSP-DSG1	1.05E-01	1.0855	Fail to recover OSP given U2 * 1 FTR * No SSW PHV failures	This term represents a failure to recover offsite power. Phase II SAMAs 1, 2, 3, 11, 12, 14 and 15 for extending available recovery time by improving DC power were evaluated.
NRC-OSP-DSG2	4.53E-02	1.0126	Fail to recover OSP given U2 * 2 FTR * No SSW PHV failures	This term represents a failure to recover offsite power. Phase II SAMAs 1, 2, 3, 11, 12, 14 and 15 for extending available recovery time by improving DC power were evaluated.
NRC-OSP-PSG0	7.63E-01	1.0134	Fail to recover OSP given SRV LOCA * U2 * 0 FTR * No SSW PHV failures	This term represents a failure to recover offsite power. Phase II SAMAs 1, 2, 3, 11, 12, 14 and 15 for extending available recovery time by improving DC power were evaluated.
NRC-SSWPH-VENT	3.80E-04	1.0054	Failure to install alternate means of cooling to SSW pump house	This term represents a failure of a human action to install alternate means of cooling to the SSW pump house. Phase II SAMA 58 for increasing training emphasis and providing control room indication on status of the SSW pump house HVAC was evaluated.
NR-PCS-60MN	6.00E-01	1.0402	Failure to recover PCS in 60 minutes	This term represents a failure of a human action to restore feedwater and manually depressurize. Phase II SAMA 20 for improving high pressure injection capability was evaluated.
NRS-ALT-PWR-SUP	4.50E-04	1.0068	Failure to align alternate power to 4.16 kV or 6.9 kV buses	This term represents a failure of a human action to align alternate power to 4.16 kV or 6.9 kV buses. Phase II SAMA 6 for improving 4.16kV bus cross-tie ability was evaluated.
NRS-DEP-LONG	1.20E-05	1.1703	Failure to manually depressurize with ADS/SRVs (after more than 2 hours)	This term represents a failure of a human action to manually depressurize with ADS/SRVs after more than 2 hours. Phase II SAMAs 22 and 37 to add larger accumulators and improve SRV pneumatic components were evaluated.

Table E.1-2
Correlation of Level 1 Risk Significant Terms to Evaluated SAMAs (Based on CDF)

Event Name	Probability	RRW	Event Description	Disposition
NRS-DEP-SHORT	3.20E-04	1.1895	Failure to manually depressurize with ADS/ SRVs	This term represents a failure of a human action to manually depressurize with ADS/SRVs. Phase II SAMAs 22 and 37 to add larger accumulators and improve SRV pneumatic components were evaluated.
NRS-FO-SSWIA	2.20E-04	1.0104	Failure to align SSW B to cool IA compressors	This term represents a failure of a human action to align SSW B to cool IA compressors. Phase II SAMA 35 for adding IA compressors which do not require cooling was evaluated.
NRS-PCS&DEP	4.20E-05	1.037	Failure to restore feedwater and manually depressurize	This term represents a failure of a human action to restore feedwater and manually depressurize. Phase II SAMA 20 for improving high pressure injection capability was evaluated.
NRS-PCSL8&DEP	1.70E-05	1.0146	Failure to restore feedwater and manually depressurize	This term represents a failure of a human action to restore feedwater and manually depressurize. Phase II SAMA 20 for improving high pressure injection capability was evaluated.
NRS-Y47&FPW	2.20E-04	1.0074	Failure of SSW ventilation and align FPW	This term represents a failure of a human action to restore SSW ventilation and align FPW. Phase II SAMA 58 for increased training on restoring SSW ventilation and aligning FPW was evaluated.
OSP-LF-EVENTU2	1.00E+00	7.1015	RCIC failure	This term is a flag. No SAMAs need to be aligned
P1	1.13E-02	1.0087	One stuck-open relief valve	This term represents stuck-open safety relief valves. Phase II SAMA 53 for increased SRV seating reliability was evaluated.
P11-PG-XVF021-G	7.20E-05	1.007	CST suction manual valve P11-F021 plugs	This term represents a blocked suction for both HPCS and RCIC. Phase II SAMA 20 for adding alternate high pressure injection systems was evaluated.

Table E.1-2
Correlation of Level 1 Risk Significant Terms to Evaluated SAMAs (Based on CDF)

Event Name	Probability	RRW	Event Description	Disposition
P2	1.52E-03	1.0285	Two or more stuck-open relief valves	This term represents stuck-open safety relief valves. Phase II SAMA 53 for increased SRV seating reliability was evaluated.
P41-004-A	6.43E-03	1.0096	Hardware failure of DG A jacket cooler components	This term represents a failure of cooling water to EDGs. Phase II SAMAs 21 and 22 for adding a backup source of diesel cooling were evaluated.
P41-054-B	6.43E-03	1.0092	Hardware failure of DG B jacket cooler components	This term represents a failure of cooling water to EDGs. Phase II SAMAs 9 and 10 for adding a backup source of diesel cooling were evaluated.
P41-152-L	6.87E-03	1.0094	Hardware failure of RHR heat exchanger coolers Train A	This term represents a failure of the train A RHR heat exchanger coolers or isolation valves. Phase II SAMA 62 for bypassing the RHR HX SSW isolation valves was evaluated.
P41-CC-MVF001A-R	6.30E-03	1.0273	Normally closed motor operated valve F001A fails to open	This term represents a failure of cooling water to ECCS and PCS. Phase II SAMAs 26 and 27 for improving service water to ECCS and PCS were evaluated.
P41-CC-MVF001B-R	6.30E-03	1.0217	Normally closed motor driven valve F001B fails to open	This term represents a failure of cooling water to ECCS and PCS. Phase II SAMAs 26 and 27 for improving service water to ECCS and PCS were evaluated.
P41-CC-MVF005A-R	6.30E-03	1.0273	Normally closed motor driven valve F005A fails to open	This term represents a failure of cooling water to ECCS and PCS. Phase II SAMAs 26 and 27 for improving service water to ECCS and PCS were evaluated.
P41-CC-MVF005B-R	6.30E-03	1.0218	Normally closed motor driven valve F005B fails to open	This term represents a failure of cooling water to ECCS and PCS. Phase II SAMAs 26 and 27 for improving service water to ECCS and PCS were evaluated.

Table E.1-2
Correlation of Level 1 Risk Significant Terms to Evaluated SAMAs (Based on CDF)

Event Name	Probability	RRW	Event Description	Disposition
P41-CC-MVF014B-L	6.30E-03	1.0091	Motor operated valve F014B-B fails to open	This term represents a failure of the RHR HX SSW isolation valves. Phase II SAMA 62 for bypassing the RHR HX SSW isolation valves was evaluated.
P41-CF-CVDISCH-R	1.02E-05	1.0057	Common cause failure of SSW discharge check valves	This term represents a failure of cooling water to ECCS and PCS. Phase II SAMAs 26 and 27 for improving service water to ECCS and PCS were evaluated.
P41-CF-FNC003S-R	3.66E-05	1.013	CCF of 3 or more SSW cooling tower fans to start	This term represents a failure of cooling water to ECCS and PCS. Phase II SAMAs 26 and 27 for improving service water to ECCS and PCS were evaluated.
P41-CF-MVDISCH-R	6.99E-05	1.0407	CCF of SSW discharge MOVs FOO5B, FOO5A, & F011C to open	This term represents a failure of cooling water to ECCS and PCS. Phase II SAMAs 26 and 27 for improving service water to ECCS and PCS were evaluated.
P41-CF-MVF001AB	1.85E-04	1.0117	CCF of isolation valves F001A and B to open	This term represents a failure of cooling water to ECCS and PCS. Phase II SAMAs 26 and 27 for improving service water to ECCS and PCS were evaluated.
P41-CF-MVF005AB	1.85E-04	1.0069	CCF of discharge MOVs F005A and B to open	This term represents a failure of cooling water to ECCS and PCS. Phase II SAMAs 26 and 27 for improving service water to ECCS and PCS were evaluated.
P41-CF-MVF14AB-L	1.85E-04	1.0056	CCF of 2 of 2 SSW RHR HX valves to open	This term represents a failure of the RHR HX SSW isolation valves. Phase II SAMA 62 for bypassing the RHR HX SSW isolation valves was evaluated.
P41-CF-MVF68AB-L	1.85E-04	1.0056	CCF of 2 of 2 SSW RHR HX valves to open	This term represents a failure of the RHR HX SSW isolation valves. Phase II SAMA 62 for bypassing the RHR HX SSW isolation valves was evaluated.

Table E.1-2
Correlation of Level 1 Risk Significant Terms to Evaluated SAMAs (Based on CDF)

Event Name	Probability	RRW	Event Description	Disposition
P41-CF-ST-SUCT-R	1.40E-05	1.008	2 of 2 SSW suction strainers CCF to plug	This term represents a failure of cooling water to ECCS and PCS. Phase II SAMAs 26 and 27 for improving service water to ECCS and PCS were evaluated.
P41-FF-MLABST-R	1.98E-04	1.0124	Common cause start failures of SSW pumps A & B	This term represents a failure of cooling water to ECCS and PCS. Phase II SAMAs 26 and 27 for improving service water to ECCS and PCS were evaluated.
P41-FF-MLC002C-R	9.03E-04	1.0099	Train C pump start failures	This term represents a failure of cooling water to ECCS and PCS. Phase II SAMAs 26 and 27 for improving service water to ECCS and PCS were evaluated.
P41-FF-MLTCVLV-R	6.34E-03	1.0777	SSW Train C common valve hardware failures	This term represents a failure of cooling water to ECCS and PCS. Phase II SAMAs 26 and 27 for improving service water to ECCS and PCS were evaluated.
P41-FR-MPC002C-R	7.20E-04	1.0063	Motor driven pump C002C fails to continue running	This term represents a failure of cooling water to ECCS and PCS. Phase II SAMAs 26 and 27 for improving service water to ECCS and PCS were evaluated.
P41-LF-FNSSWABC	1.00E+00	1.0207	Logic flag—SSW cooling tower fans fail	This term is a flag. No SAMAs need to be aligned.
P41-MA-SSWA-R	2.53E-03	1.0069	SSW Train A unavailable due to maintenance	This term represents a failure of cooling water to ECCS and PCS. Phase II SAMAs 26 and 27 for improving service water to ECCS and PCS were evaluated.
P41-MA-SSWB-R	3.42E-03	1.0093	SSW Train B unavailable due to maintenance	This term represents a failure of cooling water to ECCS and PCS. Phase II SAMAs 26 and 27 for improving service water to ECCS and PCS were evaluated.

Table E.1-2
Correlation of Level 1 Risk Significant Terms to Evaluated SAMAs (Based on CDF)

Event Name	Probability	RRW	Event Description	Disposition
P41-MA-SSWC-R	3.84E-03	1.0386	SSW Train C unavailable due to maintenance	This term represents a failure of cooling water to ECCS and PCS. Phase II SAMAs 26 and 27 for improving service water to ECCS and PCS were evaluated.
P41-PG-ST-SUCTAR	1.39E-04	1.0089	Suct. source failure of motor pumps A & C	This term represents a failure of cooling water to ECCS and PCS. Phase II SAMAs 26 and 27 for improving service water to ECCS and PCS were evaluated.
P53-FO-HECOOLIAS	1.00E+00	1.011	Operator fails to align SSW-B to IAS compressor upon loss of TBCW	This term represents a failure of a human action to align SSW-B to the IAS compressor upon loss of TBCW. Phase II SAMA 35 for adding IA compressors which do not require cooling was evaluated.
P64-FO-HE-G	1.00E+00	1.1242	Operator fails to align firewater system for injection	This term represents a failure of a human action to align the firewater system for injection. Phase II SAMAs 24 and 25 for improved low pressure injection capability were evaluated.
P64-LF-FGSHORT	1.00E+00	1.0471	Flag for transient sequences utilizing firewater	This term is a flag. No SAMAs need to be aligned.
P75-CF-3DGR-Z	2.16E-04	1.007	CCF of all 3 EDGs to run	This term represents a common cause failure to run of 3 EDGs. Phase II SAMAs 5, 8, 9, 10, and 14 for improving EDG reliability or adding additional onsite power sources were evaluated.
P75-CF-3DGS-Z	1.53E-05	1.0054	CCF of all 3 EDGs to start	This term represents a common cause failure to start of 3 EDGs. Phase II SAMAs 5, 8, 9, 10, 14, and 16 for improving EDG reliability or adding additional onsite power sources were evaluated.
P75-FR-DG-DG11-A	4.69E-02	1.0124	DG11 fails to run	This term represents a failure of DG11 to run. Phase II SAMAs 5, 8, 9, 10, 14, and 15 for improving EDG reliability or adding additional onsite power sources were evaluated.

Table E.1-2
Correlation of Level 1 Risk Significant Terms to Evaluated SAMAs (Based on CDF)

Event Name	Probability	RRW	Event Description	Disposition
P75-FR-DG-DG12-B	4.69E-02	1.016	DG12 fails to run	This term represents a failure of DG11 to run. Phase II SAMAs 5, 8, 9, 10, 14 and 15 for improving EDG reliability or adding additional onsite power sources were evaluated.
P75-FS-DG-DG11-A	6.94E-03	1.0094	DG11 fails to start	This term represents a failure of DG11 to run. Phase II SAMAs 5, 8, 9, 10, 14 and 15 for improving EDG reliability or adding additional onsite power sources were evaluated.
P75-FS-DG-DG12-B	6.94E-03	1.0092	DG12 fails to start	This term represents a failure of DG11 to run. Phase II SAMAs 5, 8, 9, 10, 14 and 15 for improving EDG reliability or adding additional onsite power sources were evaluated.
P75-MA-DGDG11-A	1.34E-02	1.0099	DG11 in maintenance outage	This term represents a failure of DG11 to run. Phase II SAMAs 5, 8, 9, 10, 14 and 15 for improving EDG reliability or adding additional onsite power sources were evaluated.
P75-MA-DGDG12-B	1.19E-02	1.013	DG12 in maintenance outage	This term represents a failure of DG11 to run. Phase II SAMAs 5, 8, 9, 10, 14 and 15 for improving EDG reliability or adding additional onsite power sources were evaluated.
P81-FR-DG-DG13-C	4.66E-02	1.0184	DG13 fails to run	This term represents a failure DG13 to run. Phase II SAMAs 5, 8, 9, 10, and 14 for improving EDG reliability or adding additional onsite power sources were evaluated.
P81-FS-DG-DG13-C	5.97E-03	1.0101	DG13 fails to start	This term represents a failure of DG13 to start. Phase II SAMAs 5, 8, 9, 10, 14, and 16 for improving EDG reliability or adding additional onsite power sources were evaluated.
P81-MA-DGDG13-C	1.18E-02	1.0152	Diesel generator DG13 unavailable due to maintenance	This term represents maintenance of DG13. Phase II SAMAs 5, 8, 9, 10, and 14 for improving EDG reliability or adding additional onsite power sources were evaluated.

Table E.1-2
Correlation of Level 1 Risk Significant Terms to Evaluated SAMAs (Based on CDF)

Event Name	Probability	RRW	Event Description	Disposition
R20-CF-CB-BKR	2.71E-07	1.0068	CCF of feeder breakers to LCCs feeding the chargers 152-1604 & 1507	This term represents a failure of DG11 to run. Phase II SAMAs 5, 8, 9, 10, 14 and 15 for improving EDG reliability or adding additional onsite power sources were evaluated.
R20-CF-TR15-16	9.02E-07	1.0507	CCF of LCC transformers for the 15AA AND 16AB buses	This term represents a failure of the LCC transformers for the 15AA and 16AB buses Phase II SAMAs 5, 8, and 17 to install an additional generator or provide alternate feeds to essential loads from an alternate emergency bus were evaluated.
R20-CO-CB-1604-B	8.40E-06	1.0053	Feeder breaker 152-1604 fails open	This term represents a failure of the power to LCC 16BB1 and 16BB3. Phase II SAMAs 5, 8, and 17 to install an additional generator or provide alternate feeds to essential loads from an alternate emergency bus were evaluated.
R21-FO-HEESFTRM	1.00E+00	1.0202	Operator fails to transfer to alternate transformer	This term represents a failure of a human action to transfer to the alternate transformer. Phase II SAMAs 5, 6, 8, 9, 10, 14, 16, 17, and 18 for enhancing AC system reliability were evaluated.
T51-MA-CUB001-C	2.00E-03	1.0188	Fan cooler T51B001-C unavailable due to maintenance	This term represents a failure of the HPCS pump room cooler. Phase II SAMA 29 for adding HPCS HVAC procedures or hardware was evaluated.
X3	1.00E+00	1.0061	X3--depressurization via RCIC	This term represents a failure to depressurize with RCIC during a SBO. Phase II SAMAs 1, 2, 3, 11, and 12 for adding or extending battery capacity were evaluated.
X77-FF-CFSTART-U	4.85E-04	1.2754	X77 common cause start failures	This term represents a failure of EDG area ventilation. Phase II SAMAs 30, 32, and 33 for adding or enhancing EDG HVAC hardware were evaluated.

Table E.1-2
Correlation of Level 1 Risk Significant Terms to Evaluated SAMAs (Based on CDF)

Event Name	Probability	RRW	Event Description	Disposition
X77-FF-FSC001A-U	3.84E-03	1.0055	DG11 room vent start failures	This term represents a failure of EDG area ventilation. Phase II SAMAs 30, 32, and 33 for adding or enhancing EDG HVAC hardware were evaluated.
X77-FF-FSC001B-U	3.84E-03	1.0053	DG12 room vent start failures	This term represents a failure of EDG area ventilation. Phase II SAMAs 30, 32, and 33 for adding or enhancing EDG HVAC hardware were evaluated.
X77-FF-FSC002C-U	3.84E-03	1.0071	DIV 3 DG room vent start faults	This term represents a failure of EDG area ventilation. Phase II SAMAs 30, 32, and 33 for adding or enhancing EDG HVAC hardware were evaluated.
Y47-FF-FSC01AA-U	6.43E-03	1.007	Y47 Train A start failures	This term represents a failure of SSW train A pump house ventilation. Phase II SAMA 58 for increasing training emphasis and providing control room indication on status of the SSW pump house HVAC was evaluated.
Y47-FO-HEMOD-U	1.00E+00	1.0143	Operator fails to provide alternate cooling	This term represents a failure of a human action to provide alternate cooling to the SSW pump house. Phase II SAMA 58 for increasing training emphasis and providing control room indication on status of the SSW pump house HVAC was evaluated.
ZLLOCA	1.00E+00	1.036	Large LOCA sequence	This term is a flag. No SAMAs need to be aligned.
ZS1LOCA	1.00E+00	1.024	Intermediate LOCA sequences	This term is a flag. No SAMAs need to be aligned.
ZS2LOCA	1.00E+00	1.0084	Small LOCA sequences	This term is a flag. No SAMAs need to be aligned.
ZSBO	1.00E+00	1.5093	SBO sequence (HPCS DG fails)	This term is a flag. No SAMAs need to be aligned.

Table E.1-2
Correlation of Level 1 Risk Significant Terms to Evaluated SAMAs (Based on CDF)

Event Name	Probability	RRW	Event Description	Disposition
ZT1B	1.00E+00	1.0299	SBO sequence (HPCS DG success)	This term is a flag. No SAMAs need to be aligned.
ZTRAN	1.00E+00	2.2786	Transient sequence (no SBO)	This term is a flag. No SAMAs need to be aligned.

CDF Uncertainty

The uncertainty associated with core damage frequency (CDF) was estimated and documented in the GGNS Level 1 Model Revision 3 PSA Summary Report [E.1-5].

The ratio of the 95^{th} percentile CDF to the mean is about 2.38. An uncertainty factor of 3 was conservatively selected to determine the internal and external benefit with uncertainty described in Section 4.21.5.4.

E.1.2 PSA Model – Level 2 Analysis

E.1.2.1 Containment Performance Analysis

The GGNS Level 2 PSA model used for the SAMA analysis is the most recent internal events risk model which reflects power uprate conditions [E.1-4].

The GGNS Level 2 model includes two types of considerations: (1) a deterministic analysis of the physical processes for a spectrum of severe accident progressions, and (2) a probabilistic analysis component in which the likelihood of the various outcomes are assessed. The deterministic analysis examines the response of the containment to the physical processes during a severe accident. This response is performed by

- Utilization of the Modular Accident Analysis Program (MAAP) 4.0.6 code to simulate severe accidents that have been identified as dominant contributors to core damage in the Level 1 analysis, and

- Reference calculation of several hydrodynamic and heat transfer phenomena that occur during the progression of severe accidents. Examples include debris coolability, pressure spikes due to ex-vessel steam explosions, scoping calculation of direct containment heating, molten debris filling the pedestal sump and flowing over the drywell floor, containment bypass, deflagration and detonation of hydrogen, thrust forces at reactor vessel failure, liner melt-through, and thermal attack of containment penetrations.

The Level 2 analysis examined the dominant accident sequences and the resulting plant damage states (PDS) defined in Level 1. The Level 1 analysis involves the assessment of those scenarios that could lead to core damage.

A full Level 2 model was developed for GGNS. The Level 2 model consists of containment event trees (CETs) with functional nodes that represent phenomenological events and containment protection system status. The nodes were quantified using subordinate trees and logic rules. A list of the CET functional nodes and descriptions used for the Level 2 analysis is presented in Table E.1-3.

The Large Early Release Frequency (LERF) is an indicator of containment performance from the Level 2 results because the magnitude and timing of these releases provide the greatest potential for early health effects to the public. The frequency calculated is approximately 1.05E-7/ry.

LERF represents a fraction (~5.1%) of all release end states. Table E.1-4 provides a correlation between the Level 2 RRW risk significant events (severe accident phenomenon, initiating events, component failures, and operator actions) down to 1.005 identified from the GGNS Probabilistic Risk Assessment (PRA) LERF model and the SAMAs evaluated in Section E.2.

Table E.1-3
Notation and Definitions for GGNS CET Functional Nodes Description

CET Functional Node	Success Criteria	Parameter Monitored for Success Determination
Reactor Pressure Vessel (RPV) Depressurization (OP)	This function questions whether the operator depressurizes the RPV after core damage but before vessel breach. Success of this action would allow low pressure injection, if available, and would minimize the challenge to containment due to a high pressure RPV rupture. The functional success criterion for this node is defined as having the RPV depressurized (i.e., less than 100 psig) until core melt is arrested in-vessel or until the RPV is breached by debris attack. The success of the depressurization function for the RPV is similar to the criterion established in the Level 1 analysis, i.e., prior to core damage. However, there are additional phenomena (i.e., non-condensable gas generation contributing to a high containment pressure that prevents safety relief valve (SRV) operation, and potentially very high containment temperatures which could fail electrical and mechanical components of the SRVs) which can occur during the accident progression beyond core damage and pose further challenge to the operator's ability to depressurize the RPV. The success criterion is to depressurize the RPV to less than 100 psig via any of the following: • A single SRV open [MAAP case GG10500A_X].[a] • Failure of the primary system due to high temperature during core melt progression.[b] • A large or medium LOCA. Other alternatives[c] may be available but are not credited in this analysis.	RPV Pressure (< 100 psig)

Table E.1-3 (Continued)
Notation and Definitions for GGNS CET Functional Nodes Description

CET Functional Node	Success Criteria	Parameter Monitored for Success Determination
Core Melt Arrested In-Vessel (RX)	In-vessel recovery or arrest of core melt progression addresses the ability of the operating staff to restore adequate core cooling from the time the end state of the Level 1 PRA occurs (e.g., core temperature > 1800°F) until restoration of water injection make-up cannot prevent the breach of the RPV bottom head by debris. Two primary failure modes have been identified for the RPV in the literature: • Local penetration seal failure due to debris heat up and local failure at welds. • Creep rupture failure of the entire bottom head. Preventing the core melt from progressing outside the RPV requires the timely introduction of water onto the debris and intact fuel assemblies. Both timing and system requirements must be defined as part of the success criteria. There are differences in core melt progression models regarding the ability to recover adequate cooling under different circumstances. These vary from no credit for retention of debris in-vessel after core melting has begun (MAAP 3.0B), to substantial credit for recovery even after debris has accumulated in the bottom head (MAAP 4.0 and MARCH). The best estimate success criteria used in this evaluation are based on the time available from the initiation of core degradation until just before substantial core relocation occurs. This typically is on the order of 30-40 minutes. In terms of system requirements, coolant injection is assumed necessary to re-flood the RPV to above 1/3 core height. It is judged, based on deterministic calculations, that this can be accomplished using makeup systems (identified in the Severe Accident Guidelines (SAGs)) with capability greater than approximately 1000 gpm.[d]	< 1/2 core relocation calculated by MAAP.

Table E.1-3 (Continued)
Notation and Definitions for GGNS CET Functional Nodes Description

CET Functional Node	Success Criteria	Parameter Monitored for Success Determination
Igniter Operation (H2)	The functional success criterion for this event node is that the igniters operate as designed (1 of 2 divisions).	The igniter hardware (1 of 2 divisions), the AC support system, the crew action to initiate, and the H_2 analyzers allowing the initiation are all required for success.
Drywell (DW) Remains Intact (CZ)	The functional success criteria for the DW intact node are that the DW retains its pressure capability and that no early DW failure modes compromise the DW integrity. The early DW failures modeled by the CZ node are characterized by phenomenological events (e.g., steam explosions, H_2 deflagration, missile generation, direct containment heating) that are estimated to challenge containment integrity relatively quickly following core melt. Late DW failures, modeled in subsequent nodes, are characterized by extreme pressure and temperature conditions that develop slowly over the course of the accident due to inadequate debris cooling. Note that successful prevention of early DW failure does not necessarily preclude late drywell or containment failure. Therefore, successful prevention of early DW failure requires the following: • No direct containment heating (direct containment heating is precluded if the RPV is already depressurized). • No ex-vessel steam explosion. • No failure of vapor suppression (the suppression pool is not bypassed and no more than 1 drywell to wetwell vacuum breaker fails open). (cont. below)	No energetic events and no DW internal pressure > 65 psig. No energetic events and no DW differential pressure > 42 psid.

Table E.1-3 (Continued)
Notation and Definitions for GGNS CET Functional Nodes Description

CET Functional Node	Success Criteria	Parameter Monitored for Success Determination
Drywell Remains Intact (CZ) (cont.)	• No in-vessel steam explosion (in-vessel steam explosions are precluded if either the RPV is at high pressure, e.g., greater than 100 psig, or the core does not fragment into fine particles before dropping onto the bottom head). • No high pressure spike sufficient to cause DW failure occurs at the time of vessel melt-through (extreme pressure spikes are precluded if the RPV bottom head penetration fails locally or if the RPV remains at low pressure). • No hydrogen deflagration or detonation (if the containment remains steam inert or effective combustible gas igniters operated successfully, then hydrogen detonation or deflagration is guaranteed not to occur). • Containment water pool remains intact. • Upper pool dump operates as needed for those accident scenarios requiring water to cover the top row of horizontal vents. If these failure modes cannot be prevented, large DW failure is assumed to occur. The failure location is assumed to be in the drywell head region and is classified as a large failure.	
Containment Remains Intact (CX)	The functional success criteria for the containment intact node are that the containment retains its pressure capability and that no early containment failure modes compromise the containment integrity. The early containment failures modeled by the CZ node are characterized by phenomenological events (e.g., steam explosions, H_2 deflagration, missile generation, direct containment heating) that are estimated to challenge containment integrity relatively quickly following core melt. Late containment failures modeled in subsequent nodes are characterized by extreme pressure and temperature conditions that develop slowly over the course of the accident due to inadequate debris cooling. (cont. below)	No energetic containment failure with internal pressure > 65 psig or the containment profile curve. No containment differential pressure > 42 psid.

Table E.1-3 (Continued)
Notation and Definitions for GGNS CET Functional Nodes Description

CET Functional Node	Success Criteria	Parameter Monitored for Success Determination
Containment Remains Intact (CX) (cont.)	Note that successful prevention of early containment failure does not necessarily preclude late containment failure. Therefore, successful prevention of early containment failure requires the following: • No direct containment heating (direct containment heating is precluded if the RPV is already depressurized). • No ex-vessel steam explosion. • No failure of vapor suppression (the suppression pool is not bypassed and no more than 1 drywell to wetwell vacuum breaker fails open). • No in-vessel steam explosion (in-vessel steam explosions are precluded if either the RPV is at high pressure, e.g., greater than 100 psig, or the core does not fragment into fine particles before dropping onto the bottom head). • No high pressure spike sufficient to cause containment failure occurs at the time of vessel melt-through (extreme pressure spikes are precluded if the RPV bottom head penetration fails locally or if the RPV remains at low pressure). • No hydrogen deflagration or detonation (if the containment remains steam inert or effective combustible gas igniters operated successfully, then hydrogen detonation or deflagration is guaranteed not to occur). • No continuous RPV blowdown at high pressure via the SRVs or horizontal vents with the suppression pool temperature above 260°F. If these failure modes cannot be prevented, containment failure is assumed to occur. The failure location is assumed to be probabilistically distributed in either the containment airspace above the Aux. Bldg. or the basemat junction with the containment cylinder and is classified as a large failure.	

Table E.1-3 (Continued)
Notation and Definitions for GGNS CET Functional Nodes Description

CET Functional Node	Success Criteria	Parameter Monitored for Success Determination
Containment Isolation (IS)	The success of the containment isolation node (IS) is satisfied if the containment penetrations that communicate between the RPV, drywell, or wetwell atmosphere and the secondary containment (or environment) are "closed and isolated." The criteria used to satisfy this requirement of "closed and isolated" is that no line, hatch, or penetration has an opening greater than 2 inches in diameter. This implies that all containment penetrations are adequately sealed and isolated during the entire accident progression until either (1) a safe stable state is reached, or (2) the accident conditions exceed the ultimate capability of containment as determined in the plant specific evaluation.	Failure size (< 2 inch dia.)
Drywell Isolation (DL)	The success of the drywell isolation node (DL) is that the drywell penetrations that allow communication from inside the DW to outside the DW are "closed and isolated." The criteria used to satisfy this requirement of "closed and isolated" is that no line, hatch, or penetration has an opening greater than 2 inches in diameter.	Failure size (< 2 inch dia.)

Table E.1-3 (Continued)
Notation and Definitions for GGNS CET Functional Nodes Description

CET Functional Node	Success Criteria	Parameter Monitored for Success Determination
Debris Cooling (SI)	Success at this node requires that water is available (greater than 1000 gpm) to the core debris at the time of vessel failure or shortly thereafter (< 2 hours). Continuous water injection either directed into the failed RPV or into the drywell will provide for the following: • Mitigation of high drywell gas temperatures. • Water overburden to scrub fission products resulting from possible core concrete interaction. • Potential for debris coolability. These are considered substantially mitigated if on a best estimate basis a continuous water supply is available to the debris with a flow rate of greater than 1000 gpm. The active mitigation methods that may provide coolant injection to the debris bed include continued make-up to the RPV and containment flooding. These effects would influence the integrity of the DW. Note that inadequate water injection will be modeled for the purposes of consequence evaluation as inducing a drywell failure high in the DW. However, there are some models that indicate that concrete attack and non-condensable gas generation will not be terminated even if substantial water injection is available to the debris. The temperatures in the drywell will be acceptable, but continued non-condensable gas generation will occur. MAAP sensitivity analyses with minimum heat transfer between debris and water indicate this is not a LERF contributor. Continued concrete attack of the pedestal can result in pedestal failure and consequential failure of the drywell penetrations if the RPV support by the pedestal is compromised.	Flow > 1000 gpm

Table E.1-3 (Continued)
Notation and Definitions for GGNS CET Functional Nodes Description

CET Functional Node	Success Criteria	Parameter Monitored for Success Determination
Containment Flooding Initiated (FC)	Success at this node implies that the containment flooding contingency procedure has been initiated by the operating staff and that a system of adequate flow capacity from external sources is available to implement the procedure. In addition to these two requirements, the instrumentation must be available to initiate the flood operation. This node evaluates the possibility that the operator suspends containment flooding because the staff is unable to maintain containment conditions within prescribed limits described in the Emergency Operating Procedures (EOPs) or SAGs. Containment venting can have varying degrees of releases associated with it depending on the following: • When in the containment flood process containment venting is possible, but not required if RPV is breached. • Whether success of suppression pool cooling and injection is effective in controlling containment pressure. Success at this juncture in the model is defined as the continuation of the flooding evolution with containment conditions remaining within the limits of the Primary Containment Pressure Limit (PCPL). MAAP calculations indicate that containment flooding through the RPV, containment cooling return, or containment sprays results in a very low radionuclide release [MAAP GG10522].	External flow > 1000 gpm Vent > 6 inch dia.

Table E.1-3 (Continued)
Notation and Definitions for GGNS CET Functional Nodes Description

CET Functional Node	Success Criteria	Parameter Monitored for Success Determination
Containment Pressure Control (see node descriptions HR and VC below)	Successful containment pressure control is achieved if either of two functional nodes are successfully satisfied: 1. Containment heat removal via pool cooling or 2. Containment venting Because these have different potential impacts on the radionuclide releases they are treated in separate nodes (see nodes HR and VC below).	1. Cont. pressure < 65 psig 2. Cont. pressure < 22.4 psig (Venting)

Table E.1-3 (Continued)
Notation and Definitions for GGNS CET Functional Nodes Description

CET Functional Node	Success Criteria	Parameter Monitored for Success Determination
Containment Heat Removal (HR)	Successful containment pressure control is unattainable using suppression pool cooling if either of the following conditions occurs: • No debris cooling (in-vessel or ex-vessel). • Early containment failure. Residual heat removal (RHR) has the capability to remove heat from containment through the RHR heat exchangers.[e] This capability requires the following: • A flow path from the suppression pool. • One low pressure coolant injection pump (LPCI) pump. • One LPCI pump heat exchanger. • SSW to cool the heat exchanger. • A return flow path to the suppression pool, the RPV, or the containment spray. • Bypass of the low RPV water level (2/3 core height) interlock if not using RPV return. Failure at this juncture in the sequence implies insufficient containment heat rejection to the environment and continued decay heat generation which could subject the containment to continued pressurization. This condition may eventually cause structural failure, which could subsequently threaten continued successful core coolant injection. Note that RHR success is a moot point if adequate injection to the core or debris has failed. This is because high temperatures from debris radiative heating or high pressure from non-condensable gases will cause drywell failure and containment failure. (MAAP Case GG10506B)	Containment pressure < 65 psig

Table E.1-3 (Continued)
Notation and Definitions for GGNS CET Functional Nodes Description

CET Functional Node	Success Criteria	Parameter Monitored for Success Determination
Containment Venting (VC)	The capability to vent the containment is a valuable supplement to the containment pressure control systems. As pressure and temperature increase, there is decreasing confidence in the ability to maintain the integrity of the containment pressure boundary. By instituting a controlled vent of the containment atmosphere, it is possible to maintain long-term containment integrity by providing a viable means of containment pressure control and heat removal. Venting also constitutes a viable mitigative action to minimize the source term released to the environment. Containment venting is successful if it can remove the excess heat and non-condensable gases from the containment and thereby maintain the containment pressure within acceptable limits. Adequate pressure control can be obtained by containment venting if the following conditions are met: • Reactivity control exists. • No "early" containment failure modes occur. • Containment flooding does not eliminate the venting pathways. • Vent pathways can be opened and controlled. Based upon deterministic calculations, a containment vent of approximately 6 inches in diameter will provide sufficient vent capability to prevent containment failure for sequences involving the loss of containment heat removal or severe accidents. Currently, no vent capability is considered successful for ATWS failure to scram events.	Containment pressure < 22.4 psig

Table E.1-3 (Continued)
Notation and Definitions for GGNS CET Functional Nodes Description

CET Functional Node	Success Criteria	Parameter Monitored for Success Determination
No Suppression Pool Bypass (SP)	This node in the CET is used to characterize the magnitude of radionuclides that may escape the containment if wetwell failure or venting occurs. Success means that radionuclides are directed through the suppression pool. Subsequent headings address specific release paths. Success in preventing suppression pool bypass requires the following: • Vacuum breakers remain closed. • The suppression pool water level remains above the horizontal vents. • The drywell does not rupture or fail.	Bypass path < 6 inch dia.
Wetwell Airspace Breach (WW) (Scrubbed Release)	This node appears after the "No Suppression Pool Bypass" node, i.e., drywell intact. This node distinguishes whether the wetwell failure occurred above or below the wetwell water line. Successfully avoiding a large containment failure requires successful containment heat removal. The probabilistic determination of the location of the failure is determined based on the plant specific structural analysis for slow overpressurization events.	No WW water release path > 2 inch dia. Success (Up Branches) containment failure in the dome (Wetwell Airspace.)
Containment Spray (CSS)	This node distinguishes radionuclide release magnitude based on the availability of the CSS.	1 train of CSS operating
Enclosure Building/Auxiliary Building Effective (EB)	Preservation of the auxiliary building and enclosure building integrity results in a calculated decontamination factor (DF) using MAAP of > 10.	DF > 10 (Not currently modeled in MAAP or in the CET)

a. A plant specific assessment of the Grand Gulf response to a high pressure core melt with a single ADS valve opened when the RPV level reaches top of active fuel. This was illustrated in MAAP Case GG10500A_X.
b. Primary system failure may be induced by very high internal temperatures generated by molten debris in an un-cooled state within the RPV. Such high temperatures coincident with high RPV pressures may lead to localized failures at weak points high within the RPV.
c. Opening MSIVs is not credited because this action is not directed by the EOPs when fuel damage has occurred.

d. The 1000 gpm criterion is an approximation. There is a comparatively large degree of uncertainty surrounding this issue. However, ORNL and GE calculations seem to indicate that an injection rate close to 1000 gpm initiated at thirty minutes may be sufficient. The EPRI Technical Basis Report also indicates that this flow rate is adequate. The flow rate is needed to match both the decay heat and the chemical (exothermic) heat generated during postulated core melt progression scenarios.
e. Other modes of containment heat removal are not considered effective because of interlocks or procedural restrictions under severe accident conditions (e.g., RWCU, Main Condenser).

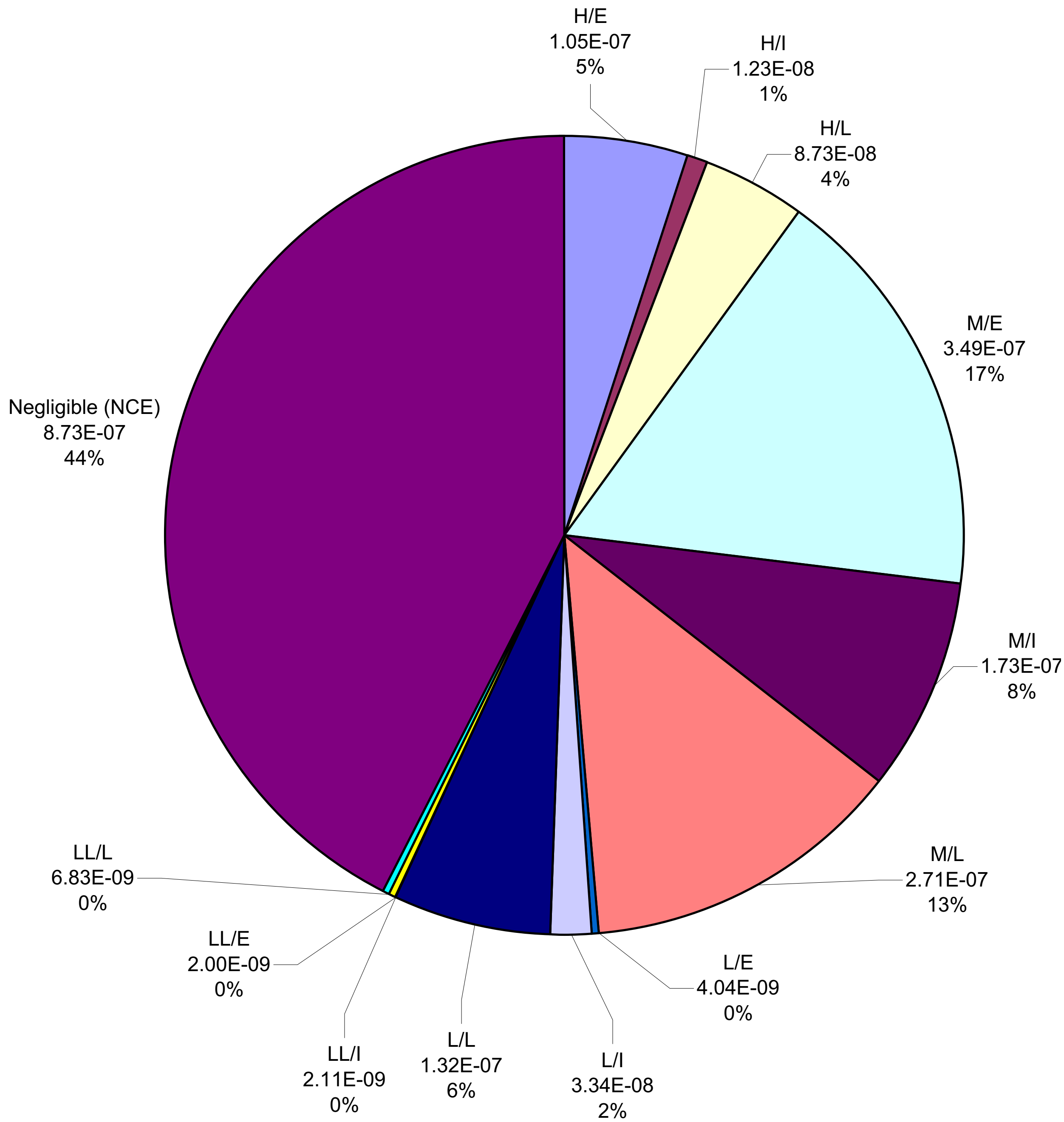

Figure E.1-1
GGNS Radionuclide Release Category Summary

Note: See Tables E.1-5 and E.1-6 for a definition of the release categories.

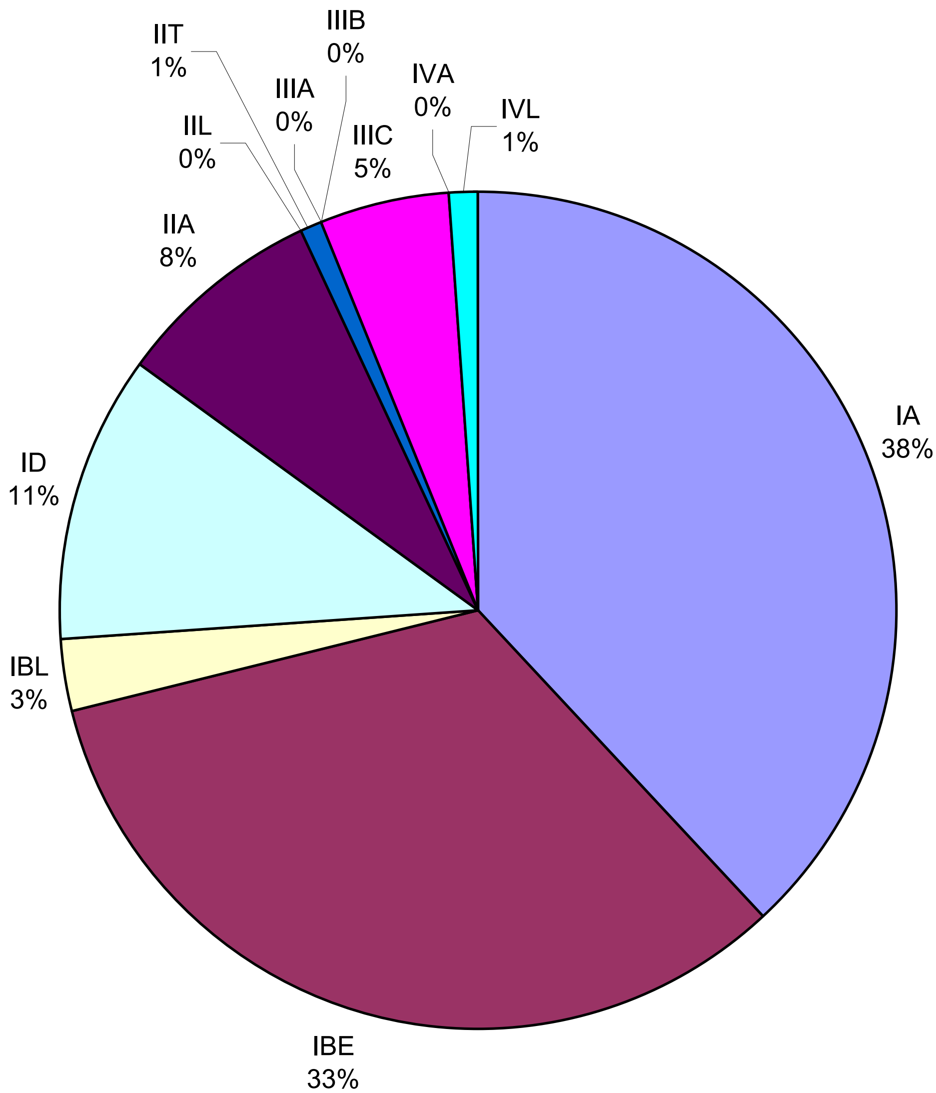

Figure E.1-2
Summary of GGNS Core Damage Accident Sequences Plant Damage States

Note: Core Damage Accident Sequences Plant Damage State definitions can be seen in Table E.1-7.

Table E.1-4
Correlation of Level II Risk Significant Terms to Evaluated SAMAs (Based on Large Early Release Frequency)

Event Name	Probability	RRW	Event Description	Disposition
B21-LF-FGCTISO	1.00E+00	1.0054	Containment isolation signal present	This term is a flag. No SAMAs need to be aligned.
CX2-PH-CZF-NOTSU	5.46E-01	1.024	Containment success during severe phenomena (CZ=F, CL II)	This term is a split fraction. No SAMAs need to be aligned.
CX2-PH-CZS-NOTSU	9.82E-01	1.0173	Containment success during severe phenomena (CZ=S, CL II)	This term is a split fraction. No SAMAs need to be aligned.
CX--PH-CTCOND-F-	5.00E-01	6.317	Probability cont. fails given H2 late ignition	This term represents a failure to control hydrogen or hydrogen ignition. Phase II SAMAs 44 and 45 for reducing the hydrogen detonation potential were evaluated.
CX--PH-H2-DEFGF-	1.00E+00	7.7756	Hydrogen deflagration occurs globally	This term represents a failure to control hydrogen or hydrogen ignition. Phase II SAMAs 44 and 45 for reducing the hydrogen detonation potential were evaluated.
CX--PH-H2INVENF-	1.00E+00	7.7756	Sufficient hydrogen generated to cause overpressure	This term represents a failure to control hydrogen or hydrogen ignition. Phase II SAMAs 44 and 45 for reducing the hydrogen detonation potential were evaluated.
CX-PH-LOOP-30MIN	8.00E-01	1.7986	AC power not recovered in 30 min	This term represents a failure to recover offsite power. Phase II SAMAs 1, 2, 3, 11, 12 and 15 for extending available recovery time by improving DC power were evaluated.
CX--PH-STEAM--F-	9.00E-01	7.7756	Containment not inerted by steam	This term represents a failure to control hydrogen or hydrogen ignition. Phase II SAMAs 44 and 45 for reducing the hydrogen detonation potential were evaluated.

Table E.1-4 (Continued)
Correlation of Level II Risk Significant Terms to Evaluated SAMAs (Based on Large Early Release Frequency)

Event Name	Probability	RRW	Event Description	Disposition
CZ2-PH-ID-NOTSU	6.60E-01	1.0284	Drywell does not fail due to severe phenomena (IGA=F, CLS ID)	This term is a split fraction. No SAMAs need to be aligned.
CZ4-PH-IGF-NOTSU	9.08E-01	1.008	Drywell does not fail due to severe phenomena (IGA=F)	This term is a split fraction. No SAMAs need to be aligned.
CZ5-PH-IBE-NOTSU	9.13E-01	1.0871	Drywell does not fail due to severe phenomena (CLASS IBE)	This term is a split fraction. No SAMAs need to be aligned.
CZ--PH-2-NOTSU	9.87E-01	1.0177	Drywell does not fail due to severe phenomena (CLASS II)	This term is a split fraction. No SAMAs need to be aligned.
CZ--PH-CRDMELTF-	1.00E+00	1.1012	Control rods melt prior to fuel rods	This term represents a possible reactivity excursion due to control rods melting before the fuel rods. Phase II SAMAs 20, 21, 22, and 28 for improving high pressure injection capability were evaluated.
CZ--PH-DWFAIL-F-	5.00E-01	5.3793	Conditional probability drywell fails given deflagration	This term represents a failure to control hydrogen or hydrogen ignition. Phase II SAMAs 44 and 45 for reducing the hydrogen detonation potential were evaluated.

Table E.1-4 (Continued)
Correlation of Level II Risk Significant Terms to Evaluated SAMAs (Based on Large Early Release Frequency)

Event Name	Probability	RRW	Event Description	Disposition
CZ--PH-FUELRODF-	1.00E-02	1.1012	Fuel rod integrity is maintined during the reflood	This term represents timely restoration of emergency core cooling to arrest the core melt progression in-vessel. Phase II SAMAs 20, 21, 22, and 28 for improving high pressure injection capability were evaluated.
CZ--PH-SLCLWL-F-	1.00E+00	1.1012	Failure to inject SLC with boron for low water level	This term represents a failure of a human action to inject SLC with boron for low water level. Phase II SAMAs 20 and 52 for improving high pressure injection and SLC capability were evaluated.
E12-FO-HECS-N	1.00E+00	1.0101	Operator fails to actuate containment spray	This term represents a failure of a human action to actuate containment spray. Phase II SAMAs 46, 47, and 60 for improving containment vent capability were evaluated.
E12-FO-HEECCS-G	1.00E+00	1.0058	Operator fails to initiate LP ECCS	This term represents a failure of a human action to initiate low pressure ECCS. Phase II SAMAs 20, 21, 22, and 28 for improving high pressure injection capability were evaluated.
E12-FO-HESPC-M	1.00E+00	1.0101	Operator fails to manually align for suppression pool cooling	This term represents a failure of a human action to manually align for suppression pool cooling. Phase II SAMAs 46 and 47 for improving containment vent capability were evaluated.
E61-FO-H2-GB-X	1.00E+00	1.0074	Failure to obtain grab sample in SAPs	This term represents a failure of a human action obtain grab sample in SAPs. Phase II SAMAs 44 and 45 for installing a passive hydrogen control system were evaluated.
E61-FO-IG-L1-X	1.00E+00	1.2301	Failure to initiate igniters before transition to SAP	This term represents a failure of a human action to initiate igniters before transition to SAP. Phase II SAMAs 44 and 45 for installing a passive hydrogen control system were evaluated.

Table E.1-4 (Continued)
Correlation of Level II Risk Significant Terms to Evaluated SAMAs (Based on Large Early Release Frequency)

Event Name	Probability	RRW	Event Description	Disposition
E61-FO-MSH13-X	1.00E+00	1.2191	Operator fails to energize hydrogen igniters	This term represents a failure of a human action to energize the hydrogen igniters. Phase II SAMAs 44 and 45 for installing a passive hydrogen control system were evaluated.
EV	1.00E+00	1.0808	Early declaration of general emergency	This term is a flag to represent an early declaration of a general emergency. No SAMAs need to be aligned.
G-IGNITION	5.38E-01	1.7464	Ignition source available at the incorrect time	This term represents a failure to control hydrogen or hydrogen ignition. Phase II SAMAs 44 and 45 for reducing the hydrogen detonation potential were evaluated.
HI--PH-H2IGSBOF-	2.50E-01	1.7986	Random hydrogen ignition given no AC power	This term represents a failure to control hydrogen or hydrogen ignition. Phase II SAMAs 44 and 45 for reducing the hydrogen detonation potential were evaluated.
IGA-PH-ID1-NOTSU	4.97E-01	1.0202	Igniters successful (CLASS ID)	This term is a split fraction. No SAMAs need to be aligned.
IGNITERS-FAIL	1.00E+00	1.0828	Igniters are operating	This term is a flag. No SAMAs need to be aligned.
IGNITERS-SUC	1.00E+00	1.0356	Ingiters are operating	This term is a flag. No SAMAs need to be aligned.
M41-FO-AVVCNT-Q	1.00E+00	1.0058	Operator fails to vent containment	This term represents a failure of a human action to vent containment. Phase II SAMA 46 for a passive containment vent was evaluated.
NRC-L2-DEPB&IG	3.38E-05	1.0059	Failure to connect ADS bottles and initiate H2 igniters	This term represents a failure of a human action to emergency depressurize, igniter initiation in level 1, and igniter initiation in level 2. Phase II SAMAs 44 and 45 for installing a passive hydrogen control system were evaluated.

Table E.1-4 (Continued)
Correlation of Level II Risk Significant Terms to Evaluated SAMAs (Based on Large Early Release Frequency)

Event Name	Probability	RRW	Event Description	Disposition
NRC-OSP-DSG3	2.87E-02	1.0153	Fail to recover OSP given U2 * 3 FTR * No SSW PHV failures	This term represents a failure to recover offsite power. Phase II SAMAs 1, 2, 3, 11, 12 and 15 for extending available recovery time by improving DC power were evaluated.
NRS-ALTPW&DEP	1.00E-06	1.0052	Failure to align alternate power and depressurize	This term represents a failure of a human action to align alternate power and depressurize. Phase II SAMAs 1, 2, 3, 11, 12, and 15 for extending available recovery time by improving DC power were evaluated.
NRS-DHRLT	1.00E-07	1.0058	Failure to initiate SPC and containment spray	This term represents a failure of a human action to initiate SPC and containment spray. Phase II SAMA 60 for improved containment heat removal were evaluated.
NRS-L2-DEP&IG	8.32E-06	1.0716	Failure to depressurize and start H2 igniters	This term represents the operator to fail the following initiation: Emergency depressurization, igniter initiation in level 1, and igniter initiation in level 2. Phase II SAMAs 44 and 45 for installing a passive hydrogen control system were evaluated.
NRS-L2-DEP&IG&FW	3.53E-06	1.0669	Failure to depressurize and start H2 igniters and restart FW pumps	This term represents the operator to fail the following initiation: Emergency depressurization, igniter initiation in level 1, igniter initiation in level 2, and failure to restart FW. Phase II SAMAs 44 and 45 for installing a passive hydrogen control system were evaluated.
NRS-L2-DEP&IG&PCS	1.43E-06	1.0243	Failure to depressurize and start H2 igniters and align PCS	This term represents the operator to fail the following initiation: Emergency depressurization, igniter initiation in level 1, igniter initiation in level 2, and align PCS. Phase II SAMAs 44 and 45 for installing a passive hydrogen control system were evaluated.

Table E.1-4 (Continued)
Correlation of Level II Risk Significant Terms to Evaluated SAMAs (Based on Large Early Release Frequency)

Event Name	Probability	RRW	Event Description	Disposition
OP--AD-ALTRNT-F-	1.00E+00	1.0577	Alternate depress. methods not credited	This is a term to flag not crediting several primary system depressurization schemes. No SAMAs need to be aligned.
OP--OP-DEPRESSH-	9.68E-01	1.0544	OP fails to depress given OP failed in LVL1 or loss of DC	This term represents a failure of a human action to depressurize given that the operator failed in the level 1 model or a loss of DC. Phase II SAMAs 1, 2, 3, 11, 12, and 15 for extending available recovery time by improving DC power were evaluated.
OP--PH-OP1-NOTSU	7.11E-01	1.1331	Successful RPV depressurization (Class IA, IE)	This term is a split fraction. No SAMAs need to be aligned.
OP--PH-OP6-NOTSU	9.75E-01	1.0801	Successful RPV depressurization (Class II)	This term is a split fraction. No SAMAs need to be aligned.
OP--PH-PRESBK-F-	8.00E-01	1.0577	Pressure transient does not fail mechanical systems	This term represents a high pressure vessel breach scenario where mechanical stress failures of the primary system pressure boundary failed to depressurize the RPV. There are no applicable SAMAs for this scenario.
OP--PH-SORV---F-	5.50E-01	1.0577	SRVs do not fail open during core melt progression	This term represents a high pressure vessel breach scenario where the SRVs failed to stick open and allow depressurization. There are no applicable SAMAs for this scenario.
OP--PH-TEMPBK-F-	7.00E-01	1.0577	High prim sys temp does not cause fail of RCS press. bound	This term represents a high pressure vessel breach scenario where the RPV pressure boundary did not rupture due to high internal RPV pressure and temperature. There are no applicable SAMAs for this scenario.

Table E.1-4 (Continued)
Correlation of Level II Risk Significant Terms to Evaluated SAMAs (Based on Large Early Release Frequency)

Event Name	Probability	RRW	Event Description	Disposition
P41-CF-MV-DGIN-R	1.85E-04	1.0065	CCF of DG inlet isol MOVs FO18A-A AND F018B-B to open	This term represents a failure EDG cooling water due to isolation valve failures on the EDG. Phase II SAMAs 5, 8, 9, and 10 for adding an additional generator and increasing the reliability of EDG cooling water were evaluated.
P64-PH-RX-EXO-F-	1.00E+00	1.2536	FPS (Paths 1-8) inadequate for 1000gpm for Rx node	This term is a flag. No SAMAs need to be aligned.
P75-CF-DGR-Z	1.43E-03	1.0104	CCF of Div 1 & Div 2 (& not Div 3) EDGs to run	This term represents a failure of the emergency AC power. Phase II SAMAs 5, 8, 9, 10, 11, 12 and 14 for improving EDG reliability or adding additional onsite power sources were evaluated.
RP--OP-L2-CRODH-	1.00E+00	1.1012	Operator restores coolant injec. after ctrl rods are melted	This term represents a failure of a human action to restore coolant injection after the control rods are melted. Phase II SAMAs 20, 21, 22, and 28 for improving high pressure injection capability were evaluated.
RXF	1.00E+00	1.0841	Failure of RX (OP=F or Classes IBE, II, IIID, and IV)	This is a flag indicating that the RPV is at high pressure with low pressure injection systems not available or viable. No SAMAs need to be aligned.
RX--PH-RX2DNOTSU	1.09E-01	1.017	Core melt arrested in-vessel (OP=S, Class ID)	This term is a split fraction. No SAMAs need to be aligned.
RX--RX-FRECINJH-	9.00E-01	1.2536	Operator fails to recover injection before RPV melt	This term represents a failure of a human action to recover injection before the RPV melt. Phase II SAMAs 20, 21, 22, and 28 for improving high pressure injection capability were evaluated.

Table E.1-4 (Continued)
Correlation of Level II Risk Significant Terms to Evaluated SAMAs (Based on Large Early Release Frequency)

Event Name	Probability	RRW	Event Description	Disposition
SP--PH-BKFLOW-F-	1.00E-01	1.0352	No backflow if SPMU fails	This term represents a suppression pool bypass after a core melt and vessel breach. Phase II SAMA 43 for installing a filtered vent was evaluated.
SP--PH-BKIGA-F-	1.00E+00	1.0826	No backflow if SPMU fails	This term represents a suppression pool bypass after a core melt and vessel breach. Phase II SAMA 43 for installing a filtered vent was evaluated.
SP--VB-SEALS--F-	1.00E-02	1.0178	Temperature induced failure of all vacuum breaker seals	This term represents a suppression pool bypass after a core melt and vessel breach. Phase II SAMA 43 for installing a filtered vent was evaluated.
SP--VB-SEALSNWF-	5.00E-02	1.0206	Temp induced failure of all vacuum breaker seals (RX=F, SI=F)	This term represents a suppression pool bypass after a core melt and vessel breach. Phase II SAMA 43 for installing a filtered vent was evaluated.
WW--WW-L2-FAIL--	1.00E-02	1.0196	Containment breach below the wtr line (Class I, IIA, IIT, III, IV)	This term is a split fraction. No SAMAs need to be aligned.
WW--WW-L2-NOT---	9.90E-01	1.2389	Containment breach above the wtr line (Class I, IIA, IIT, III, IV)	This term is a split fraction. No SAMAs need to be aligned.

Note: Basic events that are correlated in Table E.1-2 are not listed again in Table E.1-4 if they are equivalent basic events.

E.1.2.2 Radionuclide Analysis

E.1.2.2.1 Introduction

A major feature of a Level 2 analysis is the estimation of the source term for every possible outcome of the CET. The CET end points represent the outcomes of possible in-containment accident progression sequences. These end points represent complete severe accident sequences from initiating event to release of radionuclides to the environment. The Level 1 and plant system information is passed through to the CET evaluation in discrete PDS. An atmospheric source term may be associated with each of these CET sequences. Because of the large number of postulated accident scenarios considered, mechanistic calculations (i.e., MAAP calculations) are not performed for every end-state in the CET. Rather, accident sequences produced by the CET are grouped or "binned" into a limited number of release categories, each of which represents all postulated accident scenarios that would produce a similar fission product source term.

The criteria used to characterize the release are the estimated magnitude of total release and the timing of the first significant release of radionuclides. The predicted source term associated with each release category, including both the timing and magnitude of the release, is determined using the results of MAAP calculations.

E.1.2.2.2 Timing of Release

Timing completely governs the extent of radioactive decay of short-lived radioisotopes prior to an off-site release and therefore has a first-order influence on immediate health effects. GGNS characterizes the release timing relative to the time at which the release begins, measured from the time of accident initiation. The following three timing categories are used:

- Early releases (E) are CET end-states involving containment failure less than 4.0 hours from declaration of a general emergency (i.e., prior to effective evacuation), for which minimal offsite protective measures have been observed to be performed in non-nuclear accidents.

- Intermediate releases (I) are CET end-states involving containment failure greater than or equal to 4.0 hours, but less than 24 hours from declaration of a general emergency, for which much of the offsite nuclear plant protective measures can be assured to be accomplished.

- Late releases (L) are CET end-states involving containment failure greater than or equal to 24 hours from declaration of a general emergency, for which offsite measures can be assumed to be fully effective.

E.1.2.2.3 Magnitude of Release

Source term results from previous risk studies suggest that categorization of release magnitude based on cesium iodide (CsI) release fractions alone are appropriate [E.1-7]. The CsI release fraction indicates the fraction of in-vessel radionuclides escaping to the environment. (Noble gas release levels are non-informative since release of the total core inventory of noble gases is essentially complete given containment failure).

The source terms were grouped into five distinct radionuclide release categories or bins according to release magnitude as follows:

(1) High (H): A radionuclide release of sufficient magnitude to have the potential to cause early fatalities. This implies a total integrated release of > 10% of the initial core inventory of CsI.

(2) Medium (M): A radionuclide release of sufficient magnitude to cause near-term health effects. This implies a total integrated release of between 1% and 10% of the initial core inventory of CsI.

(3) Low (L): A radionuclide release with the potential for latent health effects. This implies a total integrated release of between 0.1% and 1% of the initial core inventory of CsI.

(4) Low-Low (LL): A radionuclide release with undetectable or minor health effects. This implies a total integrated release of between 0% and 0.1% of the initial core inventory of CsI.

(5) Negligible (NCF) - A radionuclide release that is less than or equal to the containment design base leakage.

The "total integrated release" as used in the above categories is defined as the integrated release within 36 hours after RPV failure. If no RPV failure occurs, then the "total integrated release" is defined as the integrated release within 36 hours after accident initiation.

E.1.2.2.4 Release Category Bin Assignments

Table E.1-5 summarizes the scheme used to bin sequences with respect to magnitude of release, based on the predicted CsI release fraction and release timing. The combination of release magnitude and timing produce seven distinct release categories for source terms. These are the representative release categories presented in Table E.1-6.

Table E.1-5
Release Severity and Timing Classification Scheme Summary

Release Severity		Release Timing	
Classification Category	**Cs Iodide % in Release**	**Classification Category**	**Time of Initial Release 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)	4.0 to 24 hours
Low (L)	0.1 to 1	Early (E)	Less than 4.0 hours
Low-low (LL)	Less than 0.1		
Negligible (NCF)	0		

Table E.1-6
GGNS Release Categories

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

E.1.2.2.5 Mapping of Level 1 Results into the Various Release Categories

PDS provide the interface between the Level 1 and Level 2 analyses (i.e., between core damage accident sequences and fission product release categories). In the PDS analysis, Level 1 results were grouped ("binned") according to plant characteristics that define the status of the reactor, containment, and core cooling systems at the time of core damage. This ensures that systems important to core damage in the Level 1 event trees and the dependencies between containment and other systems are handled consistently in the Level 2 analysis. A PDS therefore represents a grouping of Level 1 sequences that defines a unique set of initial conditions that are likely to yield a similar accident progression through the Level 2 CETs and the attendant challenges to containment integrity.

From the perspective of the Level 2 assessment, PDS binning entails the transfer of specific information from the Level 1 to the Level 2 analyses.

- Equipment failures in Level 1. Equipment failures in support systems, accident prevention systems, and mitigation systems that have been noted in the Level 1 analysis are carried into the Level 2 analysis. In this latter analysis, the repair or recovery of failed equipment is not allowed unless an explicit evaluation, including a consideration of adverse environments where appropriate, has been performed as part of the Level 2 analysis.

- RPV status. The RPV pressure condition is explicitly transferred from the Level 1 analysis to the CET.

- Containment status. The containment status is explicitly transferred from the Level 1 analysis to the CET. This includes recognition of whether the containment is bypassed or is intact at the onset of core damage.

- Differences in accident sequence timing are transferred with the Level 1 sequences. Timing affects such sequences as: SBO, internal flooding, and containment bypass (ISLOCA).

This transfer of information allows timing to be properly assessed in the Level 2 analysis.

Based on the above criteria, the Level 1 results were binned into PDS. These PDS define important combinations of system states that can result in distinctly different accident progression pathways and therefore, different containment failure and source term characteristics. Table E.1-7 provides a description of the GGNS PDS that are used to summarize the Level 1 results.

Table E.1-7
Summary of GGNS Core Damage Accident Sequences Plant Damage States

Accident Class Designator	Subclass	Definition	CAFTA Model (per Rx Yr)
Class I	A	Accident sequences involving loss of inventory makeup in which the reactor pressure remains high.	1.12E-06
	B	Accident sequences involving a station blackout and loss of coolant inventory makeup. (Class IBE is defined as "Early" Station Blackout events with core damage at less than 4 hours. Class IBL is defined as "Late" Station Blackout events with core damage at greater than 4 hours.)	IBE = 9.71E-07 IBL = 8.20E-08
	C	Accident sequences involving a loss of coolant inventory induced by an ATWS sequence with containment intact.	< 1E-12
	D	Accident sequences involving a loss of coolant inventory makeup in which reactor pressure has been successfully reduced to 200 psi.	3.17E-07
	E	Accident sequences involving loss of inventory makeup in which the reactor pressure remains high and DC power is unavailable. (Grouped with Class IA.)	(Grouped with Class IA)
Class II	A	Accident sequences involving a loss of containment heat removal with the RPV initially intact; core damage; core damage induced post containment failure.	2.44E-07
	L	Accident sequences involving a loss of containment heat removal with the RPV breached but no initial core damage; core damage induced post containment failure.	9.84E-10
	T	Accident sequences involving a loss of containment heat removal with the RPV initially intact; core damage induced post high containment pressure.	1.37E-08
	V	Class IIA and IIT except that the vent operates as designed; loss of makeup occurs at some time following vent initiation. Suppression pool saturated but intact.	< 1E-12

Table E.1-7 (Continued)
Summary of GGNS Core Damage Accident Sequences Plant Damage States

Accident Class Designator	Subclass	Definition	CAFTA Model (per Rx Yr)
Class III (LOCA)	A	Accident sequences leading to core damage conditions initiated by vessel rupture where the containment integrity is not breached in the initial time phase of the accident.	1.00E-08
	B	Accident sequences initiated or resulting in small or medium LOCAs for which the reactor cannot be depressurized prior to core damage occurring.	6.39E-11
	C	Accident sequences initiated or resulting in medium or large LOCAs for which the reactor is at low pressure and no effective injection is available.	1.60E-07
	D	Accident sequences which are initiated by a LOCA or RPV failure and for which the vapor suppression system is inadequate, challenging the containment integrity with subsequent failure of makeup systems.	< 1E-12
Class IV (ATWS)	A	Accident sequences involving failure of adequate shutdown reactivity with the RPV initially intact; core damage induced post containment failure.	4.06E-09
	L	Accident sequences involving a failure of adequate shutdown reactivity with the RPV initially breached (e.g., LOCA or stuck-open relief valve (SORV)); core damage induced post containment failure.	(Grouped with Class IVA)
Class V	---	Unisolated LOCA outside containment.	4.91E-10
		Total CDF	**2.92E-06**

Note: The total CDF is not the same as the baseline CDF in Table E.1-1 due to non-minimal cutsets created when quantifying at the sequence level.

E.1.2.2.6 Process Used to Group the Source Terms

The approach used to evaluate radionuclide releases and develop release categories is similar to that applied in the NUREG-1150 [E.1-8] analysis. The objectives were to establish the timing of the first significant release of radionuclides and estimate the magnitude of the total release.

The GGNS Level 3 analysis requires, as an input, the frequency, type, timing and amount of fission products released to the environment during the core damage accidents postulated by the GGNS Level 2 PRA analyses. In order to simplify the large number of potential release scenarios, a representative set of release fractions was chosen for each containment event tree end state along with an end state frequency.

The PDS designators listed in Table E.1-7 represent the core damage end state categories from the Level 1 analysis that are grouped together as entry conditions for the Level 2 analysis. The Level 2 accident progression for each of the PDS is evaluated using a CET to determine the appropriate release category for each Level 2 sequence. Note, however, that since not all the Level 2 sequences associated with each Level 1 plant damage state may be assigned to the same release category, there is no direct link between a specific Level 1 core damage PDS and Level 2 release category. Rather, the sum of the Level 2 end state frequencies assigned to each release category determines the overall frequency of that release category.

Appendix D of the GGNS Level 2 PSA Analysis [E.1-4] describes which GGNS specific MAAP analyses are representative of each CET end state. It also bins each CET sequence into one of the release categories depicted in Table E.1-6.

For each CET sequence, a value for each of the release-to-environment mass fractions was obtained from the representative MAAP calculation. These mass fractions were then weighed according to the contribution of that sequence to the sum of the sequences in the end state bin. The final mass fraction representing the end state bin was the sum of these individual weighed mass fractions for each species.

To evaluate the Level 2 model results in a manner that provided the above information, each Level 2 CET sequence was linked to its respective CET end state (H/E, H/I, H/L, etc.). The release fraction and timing data for all sequences associated with a particular CET end state were weighted according to the sequence weight for that end state and summed to obtain a representative release fraction and release timing for that end state.

Based on the above binning methodology, the salient Level 2 results are summarized in Table E.1-8. Table E.1-8 summarizes the results of the CET quantification and identifies the total annual release frequency for each Level 2 release category.

Table E.1-8
Summary of Containment Event Tree Quantification

Release Category (Magnitude/Timing)	Release Frequency (Per ry)
H/E	1.05E-07
H/I	1.23E-08
H/L	8.73E-08
M/E	3.49E-07
M/I	1.73E-07
M/L	2.71E-07
L/E	4.04E-09
L/I	3.34E-08
L/L	1.32E-07
LL/E	2.00E-09
LL/I	2.11E-09
LL/L	6.83E-09
Negligible (NCF)	8.73E-07
CDF	**2.05E-06**

Nomenclature:

Timing (time between General Emergency Declaration and initial release):

Late (L) – Greater than 24 hours
Intermediate (I) – 4.0 to 24 hours
Early (E) – Less than 4.0 hours

Magnitude:

Negligible (NCF)– Much less than 0.1% CsI release fraction
Low-Low (LL) – Less than 0.1% CsI release fraction
Low (L) – 0.1% to 1% CsI release fraction
Medium (M) – 1% to 10% CsI release fraction
High (H) – Greater than 10% CsI release fraction

E.1.2.2.7 Consequence Analysis Source Terms

Input to the Level 3 GGNS model from the Level 2 model is a combination of radionuclide release fractions, timing of radionuclide releases, and frequencies at which the releases occur. This combination of information is used in conjunction with GGNS site characteristics in the Level 3 model to evaluate the off-site consequences of a core damage event.

Source terms were developed for the release categories identified in Table E.1-6. Table E.1-9 provides a summary of the Level 2 results that were used as Level 3 input for the GGNS SAMA analysis (the baseline analysis case).

Consequences corresponding to each of the release categories are developed in the GGNS Level 3 model, which is discussed in Section E.1.5.

E.1.2.2.8 Release Magnitude Calculations

The MAAP computer code is used to assign both the radionuclide release magnitude and timing based on the accident progression characterization. Specifically, MAAP provides the following information:

- Containment pressure and temperature (time of containment failure is determined by comparing these values with the nominal containment capability).
- Radionuclide release timing and magnitude for a large number of radioisotopes.
- Release fractions for twelve radionuclide species.

Table E.1-9
GGNS Release Category Source Terms
Sheet 1 of 2

Release Mode (CET End State)	Frequency (/year)	WarningTime (sec)	Elevation (m)	Release Start (sec)	Release Duration (sec)	Release Energy (W)
H/E	1.05E-07	966	32	1497	257703	3.0E+07
H/I	1.23E-08	12	32	37707	221493	4.3E+05
H/L	8.73E-08	992	32	112096	111104	9.1E+04
M/E	3.49E-07	957	32	59664	199536	2.9E+06
M/I	1.73E-07	12	32	90866	168334	4.3E+05
M/L	2.71E-07	992	32	116944	142256	9.1E+04
L/E	4.04E-09	787	32	1279	4733	2.4E+06
L/I	3.34E-08	1264	32	1997	257203	4.3E+05
L/L	1.32E-07	966	32	107078	152122	8.3E+05
LL/E	2.00E-09	1266	32	1996	257204	2.9E+06
LL/I	2.11E-09	1265	32	1996	257204	4.3E+05
LL/L	6.83E-09	1266	32	186290	72910	9.1E+04

Table E.1-9
GGNS Release Category Source Terms
Sheet 2 of 2

Release Mode (CET End State)	Release Fraction								
	NG	I	Cs	Te	Sr	Ru	La	Ce	Ba
H/E	1.0E+00	1.4E-02	6.1E-03	5.5E-02	4.0E-04	6.5E-05	4.7E-05	5.0E-04	1.9E-04
H/I	1.0E+00	2.2E-01	7.6E-02	1.3E-01	9.8E-06	1.1E-05	5.4E-07	9.6E-06	1.0E-05
H/L	1.0E+00	1.7E-01	4.7E-02	1.5E-01	5.9E-06	5.7E-07	6.7E-07	7.3E-06	3.6E-06
M/E	8.8E-01	1.8E-01	5.2E-02	1.1E-01	1.5E-03	9.7E-04	1.4E-04	1.7E-03	1.2E-03
M/I	1.0E+00	3.6E-02	1.5E-01	1.1E-01	3.6E-06	1.1E-05	2.6E-07	4.5E-06	9.9E-06
M/L	1.0E+00	8.4E-02	5.0E-02	4.9E-02	2.2E-07	6.2E-07	1.6E-08	2.0E-07	1.3E-06
L/E	9.1E-01	2.1E-03	2.1E-03	2.1E-03	1.2E-05	3.9E-04	2.6E-07	1.5E-06	6.4E-05
L/I	1.0E+00	8.3E-02	2.5E-02	6.9E-02	1.7E-04	4.2E-05	4.4E-06	1.3E-04	9.2E-05
L/L	1.0E+00	7.2E-03	4.5E-03	4.3E-02	4.4E-06	1.4E-06	5.0E-07	6.1E-06	4.8E-06
LL/E	2.1E-02	5.3E-06	5.4E-07	1.9E-06	2.6E-09	2.3E-07	2.0E-10	1.1E-09	6.5E-08
LL/I	1.9E-02	1.7E-06	2.6E-07	3.0E-06	1.6E-09	2.2E-07	1.2E-10	6.6E-10	4.7E-08
LL/L	9.6E-01	1.0E-02	1.7E-02	1.0E-02	1.5E-06	1.8E-06	1.3E-07	1.2E-06	1.0E-06

E.1.3 IPEEE Analysis

E.1.3.1 Seismic Analysis

The seismic portion of the IPEEE was completed in December 1994 and documented in GGNS94-0053 [E.1-9] following the guidance of NUREG-1407 [E.1-10] and EPRI NP-6041-SL [E.1-11]. The SMA approach is a deterministic and conservative evaluation that does not calculate risk on a probabilistic basis. Therefore, its results should not be compared directly with the best-estimate internal events results.

The conclusions of the GGNS IPEEE seismic margin analysis are as follows:

- Walkdowns resulted in no outliers that are operability issues at the plant.
- No unique decay heat removal vulnerabilities to seismic events were found.
- Seismic-induced flooding and fires do not pose major risks.
- No unique seismic-induced containment failure mechanisms were identified.

A number of plant improvements were identified and resolved as a result of the report. The list can be found in Appendix B of GGNS94-0053 Seismic Margins IPEEE [E.1-9].

E.1.3.2 Fire Analysis

The GGNS internal fire risk model was performed in the mid-1990's as part of the IPEEE for GGNS. The GGNS fire analysis was performed using EPRI's Fire PRA Implementation Guide [E.1-12].

Table E.1-10 presents the results of current GGNS IPEEE fire analysis.

Generic conservatisms in the IPEEE fire analysis methods mentioned in NEI 05-01 [E.1-1], "Severe Accident Mitigation Alternatives (SAMA) Analysis Guidance Document," that are applicable to the GGNS fire analysis include the following.

- The frequency and severity of fires were generally conservatively overestimated. A revised NRC fire events database indicates a trend toward lower frequency and less severe fires. This trend reflects improved housekeeping, reduction in transient fire hazards, and other improved fire protection steps at utilities.
- There is little industry experience with crew actions following fires. This led to conservative characterization of crew actions in the IPEEE fire analysis. Because CDF is strongly correlated with crew actions, this conservatism has a profound effect on fire results.

- The peer review process for fire analyses was less well developed than for internal events PSAs. For example, no industry process, such as NEI 00-02, existed for the structured peer review of a fire PSA.

Plant-specific conservative assumptions in the GGNS IPEEE fire analysis include the following.

- Certain specified components whose locations were not determined were assumed failed by any fire.
- Plant trip initiators were assumed to occur in each fire area.
- The damaging effects of a fire were assumed to affect all components in a compartment unless detailed fire modeling was done to demonstrate otherwise.
- No credit was given to human detection except when a continuous fire watch is required.
- Suppression prior to loss of a cabinet's function was not credited. This assumption was particularly important to the control room.
- The loss of a control room cabinet containing divisional equipment was assumed to affect the entire division.

Table E.1-10
GGNS Fire IPEEE Results

Fire Compartment	Compartment Description	Total Compartment CDF (/rx-yr)	Screened(1)
CA101	Auxiliary Building Corridors. 93'-0" Elevation	5.74E-07	N
CA102	RB Fire Zones 1A102, 1A202, 1A303, 1A442	1.01E-08	B
CA103	RB Fire Zones 1A103, 1A203	4.85E-08	B
CA104	RB Fire Zones 1A104, 1A204	6.76E-08	B
CA105	RB Fire Zones 1A105, 1A205	7.19E-07	B
CA106	RB Fire Zones 1A106, 1A206, 1A307, 1A441	8.56E-09	B
CA107	RB Fire Zones 1A107	2.06E-08	A
CA108	RB Fire Zones 1A108	2.06E-08	A
CA109	RB Fire Zones 1A109	6.31E-07	B
CA111	RB Fire Zones 1A111, 1A127	1.06E-08	A
CA115	RB Fire Zones 1A115, 1A116, 1A118, 1A119, 1A220	1.34E-07	C
CA124	RB Fire Zones 1A124	7.35E-09	A
CA125	RB Fire Zones 1A125	7.35E-09	A
CA130	RB Fire Zones 1A130, 1A131	7.35E-09	A
CA132	RB Fire Zones 1A132, 1A224, 1A226, 1A305, 1A439, 1A440	8.83E-09	B
CA201	Auxiliary Building Corridors. 119'-0" Elevation	6.38E-07	N
CA207	Switchgear Room 1A207	3.47E-07	C
CA208	Switchgear Room 1A208	8.14E-07	C
CA209	RB Fire Zones 1A209	1.41E-08	A
CA210	RB Fire Zones 1A210	1.41E-08	A
CA219	Switchgear Room 1A219	4.09E-07	C
CA221	Switchgear Room 1A221	4.57E-07	C
CA225	RB Fire Zones 1A225	7.35E-09	A
CA301	Auxiliary Building Corridors. 139'-0" Elevation A422, 1A324	6.70E-07	N
CA304	RB Fire Zones 1A304	7.36E-09	B
CA306	RB Fire Zones 1A306	7.36E-09	B
CA308	RB Fire Zones 1A308	2.62E-08	B
CA309	RB Fire Zones 1A309	3.57E-07	B

Table E.1-10 (Continued)
GGNS Fire IPEEE Results

Fire Compartment	Compartment Description	Total Compartment CDF (/rx-yr)	Screened(1)
CA318	RB Fire Zones 1A318	2.41E-07	B
CA319	RB Fire Zones 1A319	8.82E-09	A
CA320	RB Fire Zones 1A320	3.09E-07	B
CA323	RB Fire Zones 1A323	8.82E-09	A
CA325	RB Fire Zones 1A325	7.35E-09	A
CA326	RB Fire Zones 1A326	1.09E-08	A
CA401	RB Fire Zones 1A401, 1A403, 1A417, 1A420, 1A424, 1A427, 1A428, 1A434	1.94E-07	C
CA402	RB Fire Zones 1A402	7.35E-09	A
CA404	RB Fire Zones 1A404	7.35E-09	A
CA405	RB Fire Zones 1A405	2.94E-08	A
CA406	RB Fire Zones 1A406	1.12E-08	A
CA407	Switchgear Room 1A407	5.00E-08	B
CA410	Switchgear Room 1A410	5.00E-08	B
CA429	RB Fire Zones 1A429	1.06E-08	A
CA430	RB Fire Zones 1A430	2.73E-08	A
CA431	RB Fire Zones 1A431, 1A437, 1A438, 1A444, 1A525, 1A528, 1A532, 1A602, 1A603, 1A604, 1A606, 1A607	1.32E-07	A
CA432	RB Fire Zones 1A432	2.38E-08	A
CA433	RB Fire Zones 1A433	1.41E-08	A
CA436	RB Fire Zones 1A436	7.35E-09	A
CA506	RB Fire Zones 1A506, 1A508, 1A605	7.35E-09	A
CA519	RB Fire Zones 1A519, 1A523, 1A524, 1A527, 1A531	2.26E-08	A
CA529	RB Fire Zones 1A529	2.73E-08	B
CA530	RB Fire Zones 1A530	2.06E-08	A
CA533	RB Fire Zones 1A533	7.35E-09	A
CA534	RB Fire Zones 1A534	7.35E-09	A
CA536	RB Fire Zones 1A536	7.35E-09	A
CA537	RB Fire Zones 1A537	7.35E-09	A

Table E.1-10 (Continued)
GGNS Fire IPEEE Results

Fire Compartment	Compartment Description	Total Compartment CDF (/rx-yr)	Screened[1]
CA539	RB Fire Zones 1A539	3.45E-07	C
CC101	RB Fire Zones OC101, OC103, OC115, OC117, OC217	5.67E-08	C
CC104	Hot Machine Shop	2.42E-07	N
CC125	RB Fire Zones OC125	1.18E-08	A
CC126	RB Fire Zones OC126	2.06E-08	A
CC128	RB Fire Zones OC128	1.38E-08	B
CC202	Division 1 Switchgear Room	9.37E-07	N
CC203	RB Fire Zones OC203	2.94E-07	C
CC204	RB Fire Zones OC204	1.35E-08	A
CC205	RB Fire Zones OC205	7.35E-09	A
CC205A	RB Fire Zones OC205A	7.35E-09	A
CC206	RB Fire Zones OC206	7.35E-09	A
CC207	Battery Room OC207	8.84E-07	C
CC208	RB Fire Zones OC208	8.75E-08	B
CC208A	RB Fire Zones OC208A	3.75E-08	B
CC209	Battery Room OC209	4.63E-07	B
CC210	Division 3 (HPCS) Switchgear Room	6.08E-07	N
CC211	Battery Room OC211	2.94E-07	C
CC212	RB Fire Zones OC212	7.35E-09	A
CC213	RB Fire Zones OC213	3.86E-08	B
CC214	RB Fire Zones OC214	4.24E-07	C
CC215	Division 2 Switchgear Room	4.06E-07	N
CC216	RB Fire Zones OC216	7.36E-09	B
CC218	RB Fire Zones OC218	7.35E-09	A
CC219	RB Fire Zones OC219	7.35E-09	A
CC301	RB Fire Zones OC301	7.35E-09	A
CC302	HVAC Equipment Room	2.10E-07	N
CC303	RB Fire Zones OC303	4.42E-08	B
CC304	RB Fire Zones OC304, OC412, OC612	4.46E-08	B

Table E.1-10 (Continued)
GGNS Fire IPEEE Results

Fire Compartment	Compartment Description	Total Compartment CDF (/rx-yr)	Screened[(1)]
CC305	RB Fire Zones OC305	7.35E-09	A
CC306	RB Fire Zones OC306, OC409, OC610, OC709	1.03E-08	A
CC307	RB Fire Zones OC307	1.94E-07	C
CC308	RB Fire Zones OC308	7.36E-09	B
CC309	RB Fire Zones OC309	7.35E-09	A
CC401	RB Fire Zones OC401	7.35E-09	A
CC402	Cable Spreading Room	2.82E-07	N
CC402A	RB Fire Zones OC402A, OC512B	7.35E-09	A
CC403	RB Fire Zones OC403	1.04E-07	C
CC404	RB Fire Zones OC404	7.35E-09	A
CC405	RB Fire Zones OC405	7.35E-09	A
CC405A	RB Fire Zones OC405A, OC507A	7.35E-09	A
CC406	RB Fire Zones OC406	7.35E-09	A
CC406A	RB Fire Zones OC406A, OC518A, OC613A	7.35E-09	A
CC407	RB Fire Zones OC407	1.35E-07	A
CC408	RB Fire Zones OC408	1.05E-07	B
CC409A	RB Fire Zones OC409A, OC512, OC608B	7.35E-09	A
CC410	Battery Room OC410	1.91E-08	A
CC411	RB Fire Zones OC411	7.35E-09	A
CC412A	RB Fire Zones OC412A, OC507C, OC603B	7.35E-09	A
CC501	RB Fire Zones OC501	7.35E-09	A
CC502	Control Room	3.85E-06	N
CC507	RB Fire Zones OC507	7.35E-09	A
CC509	RB Fire Zones OC509, OC511, OC512	7.35E-09	A
CC510	RB Fire Zones OC510	7.35E-09	A
CC513	RB Fire Zones OC513	7.35E-09	A
CC514	RB Fire Zones OC514	7.35E-09	A
CC515	RB Fire Zones OC515	7.35E-09	A
CC518	RB Fire Zones OC518, OC611	7.35E-09	A

Table E.1-10 (Continued)
GGNS Fire IPEEE Results

Fire Compartment	Compartment Description	Total Compartment CDF (/rx-yr)	Screened(1)
CC601	RB Fire Zones OC601, OC602	4.58E-08	B
CC603	RB Fire Zones OC603	1.12E-08	A
CC604	RB Fire Zones OC604	9.70E-09	A
CC606	RB Fire Zones OC606	7.35E-09	A
CC608	RB Fire Zones OC608	1.03E-08	A
CC609	RB Fire Zones OC609	7.35E-09	A
CC613	RB Fire Zones OC613	7.35E-09	A
CC614	RB Fire Zones OC614	9.11E-09	A
CC615	RB Fire Zones OC615	7.35E-09	A
CC616	RB Fire Zones OC616	7.35E-09	A
CC617	RB Fire Zones OC617	7.35E-09	A
CC618	RB Fire Zones OC618	1.05E-07	B
CC619	RB Fire Zones OC619	7.35E-09	A
CC701	RB Fire Zones OC701	7.35E-09	A
CC702	Cable Spreading Room OC702	5.18E-07	C
CC703	RB Fire Zones OC703	4.72E-07	C
CC704	RB Fire Zones OC704	2.12E-08	A
CC705	RB Fire Zones OC705	8.82E-09	A
CC706	RB Fire Zones OC706	1.05E-07	B
CC707	RB Fire Zones OC707	1.09E-07	A
CC708	RB Fire Zones OC708, OC710	5.59E-08	A
CC708A	RB Fire Zones OC708A	7.35E-09	A
CC711	RB Fire Zones OC711	7.35E-09	A
CC712	RB Fire Zones OC712	7.35E-09	A
CC713	RB Fire Zones OC713	7.35E-09	A
CD301	RB Fire Zones 1D301	4.34E-08	B
CD306	Division 3 (HPCS) Diesel Generator Room	1.72E-07	N
CD308	Diesel Generator Room ID308	3.05E-07	C
CD310	Diesel Generator Room ID310	3.48E-07	C
CM100	RB Fire Zones BASIN NO. 1	2.80E-08	B

Table E.1-10 (Continued)
GGNS Fire IPEEE Results

Fire Compartment	Compartment Description	Total Compartment CDF (/rx-yr)	Screened(1)
CM110	RB Fire Zones IM110	2.56E-07	C
CM112	RB Fire Zones IM112	7.90E-07	B
CM200	RB Fire Zones BASIN NO. 2	2.90E-08	B
CM210	RB Fire Zones 2M110	7.31E-07	B
CM212	RB Fire Zones 2M112	4.02E-08	B
CT100	Turbine Building Floor, 93'-0" Elevation	3.24E-07	N
CT200	Turbine Building Floor, 113'-0" Elevation	7.10E-09	N
CT212	Battery Room 1T212	1.91E-08	A
CT219	Switchgear Room 1T219	9.23E-07	B
CT300	133'-0" Elevation, Turbine Bldg.	5.19E-07	C
CT312	Battery Room 1T312	1.91E-08	A
CT323	Switchgear Room 1T323	8.84E-07	B
CT400	166'-0" Elevation, Turbine Bldg. + 1T502, 1T503	1.63E-07	C
CT405	Battery Room 1T405	1.91E-08	A
CT406	Battery Room 1T406	1.91E-08	A
CM101	OM101 (Circ. Water Pumphouse)	6.48E-08	B
CM102	OM102 (Mtr. Driver Fire Pump Room)	1.14E-07	B
CM115	OM115 (all Water Treatment Bldg.)	2.42E-07	C
CRAD	Radwaste Bldg.	3.29E-07	C
CTR11	Transformers BOP11A, BOP11B	1.94E-07	C
CTR12	Transformers BOP12A, BOP12B	1.65E-07	B
CTR14	Transformers BOP14, BOP24	4.70E-08	A
CTRMAIN	Transformers Main 1A, 1B, 1C, 1D	8.53E-08	A
CDUC1	Division 1 duct bank to SSW Cooling Tower	3.15E-08	B
CDUC2	Division 2 duct bank to SSW Cooling Tower	2.47E-07	C
CDUC3	Division 3 duct bank to SSW Cooling Tower	2.52E-07	B
YARD	Balance of Yard Area	7.71E-07	C
	Total	**2.74E-05**	

Reference: E.1-15

1. Screening Criteria in Table E.1-10:
   - A Screened based on no safe shutdown or PRA equipment.
   - B Screened assuming all equipment in compartment is failed.
   - C Screened with credit for detailed recovery.
   - N Not screened, more detailed analysis performed.

E.1.3.3 Other External Hazards

The GGNS IPEEE submittal, in addition to the internal fires and seismic events, examined a number of other external hazards:

- High winds and tornadoes.
- External flooding.
- Ice, hazardous chemical, transportation, and nearby facility incidents.

The GGNS Individual Plant Examination of External Events (IPEEE) concluded that for high winds, floods, and other external events, GGNS meets the applicable Nuclear Regulatory Commission (NRC) requirements and therefore has an acceptably low risk with respect to these hazards. As these events are not dominant contributors to external event risk and quantitative analysis of these events is not practical, they are considered negligible.

E.1.4 PSA Model Revisions and Peer Review Summary

The summary of the GGNS PSA models CDF and LERF is presented in the table below.

Summary of Major PSA Models		
PSA Model	**CDF (/rx-yr)**	**LERF (/rx-yr)**
1992 (IPE)	1.72E-05	5.17E-07
1997 (R1)	5.46E-06	Not Updated
2002 (R2)	4.27E-06	2.04E-07
2010 (R3)	2.69E-06	1.44E-07
2010 (EPU)	2.91E-06	1.48E-07

E.1.4.1 Major Differences between the 1997(R1) PSA Model and the IPE Model

The GGNS IPE model was originally made in 1992 [E.1-13]. The NRC provided a Safety Evaluation of the IPE in March 1996 [E.1-16]. It was then updated in 1997 and was renamed the GGNS. A summary of this update is documented in GGNS Engineering Report No. GGNS-97-0014 [E.1-14]. The changes lowered the CDF to 5.46E-06/rx-yr from 1.72E-05/rx-yr. Changes to the model are summarized below:

- Incorporation of updated plant specific data for system maintenance and testing unavailability.
- Incorporation of updated plant specific data for initiating event frequencies.
- Incorporation of updated plant specific data for certain important components (i.e., diesel generators, HPCS and reactor core isolation cooling (RCIC) pumps).
- Various modeling changes to system models to correct minor modeling errors and incorporate modifications since the original IPE.

E.1.4.2 Major Differences between the 2002 (R2) PSA Model and the 1997(R1) PSA Model

The next update of the PSA model was identified as the GGNS Level 1 PSA, Revision 2. This update included plant changes through refueling outage 11, addition of an ISLOCA initiator, and operating data through 12/31/2000. It is documented in GGNS calculation XC-N1111-01007 [E.1-17]. The changes lowered the CDF to 4.27E-06/rx-yr from 5.46E-06/rx-yr. The LERF calculation was also updated and the results changed to 2.04E-07/rx-yr.

E.1.4.3 Major Differences between the 2010 (R3) PSA Model and the 2002 (R2) PSA Model

The update of the Revision 2 Model is designated as the GGNS Level 1, Revision 3 Model [E.1-5]. The following list describes the most significant changes from the 2002 (R2) model.

- Updated plant specific data (through 8-2006).
- Updated plant specific (through 8-2006) and generic initiator frequencies.
- New initiators:
  - Loss of service transformer.
  - Reactor Vessel Rupture.
  - Loss of CRD.
  - Break (LOCA) Outside of Containment.
- Major changes to LOSP modeling:
  - Added loss of preferred offsite power initiator.
  - Added consequential loss of offsite power event as a result of transient initiator.
  - Added consequential loss of offsite power event as a result of LOCA initiator.
  - New industry data used for LOSP recovery analysis.
- Separated loss of PCS initiator into Closure of MSIVs initiator and Loss of PCS due to other causes initiator.
- Updated ISLOCA analysis.
- Updated common cause analysis.
- Updated human reliability analysis.
- Included modeling for loss of ECCS pumps due to containment failure.
- Revised instrument air system modeling to incorporate new Plant Air compressors.
- Revised modeling of CRD—less credit for CRD.
- Added more detailed modeling for failure to scram.
- Added more detail to power conversion model.

The calculation PRA-GG-01-001 [E.1-5] summarizes changes incorporated in the Revision 3 model, the overall core damage frequency results, and other additional information from the Revision 3 version of the model. These changes lowered the CDF to 2.69E-06/rx-yr from 4.27E-06/rx-yr.

The LERF contribution from this model is 1.44E-07/rx-yr.

E.1.4.4 Major Differences between the 2010 (EPU) PSA Model and the 2010 (R3) PSA Model

The 2010 (R3) PSA model is based on the current licensed thermal power (CLTP) level of 3898 MWt. The 2010 EPU model uses a 13 percent increase (i.e., extended power uprate) of the CLTP to 4408 MWt.

The Grand Gulf PRA was examined to assess the impact of the following EPU changes on the PRA elements:

- Power level change

- Hardware changes
- Procedural changes
- Operational changes

The results of the PRA evaluation are the following:

- Detailed thermal hydraulic analyses of the plant response using the EPU configuration indicate reductions in the operator action "allowable" times for some actions.

- The reduced operator action "allowable" times resulted in increases in the assessed human error probabilities for some actions in the PRA model.

- Only small risk increases were identified for the changes associated with the EPU. These involved (1) reduced times available for effective operator actions and (2) minor changes in some functional success criteria in the PRA (negligible impact on results).

- The risk impact due to the implementation of the EPU is low and acceptable without the requirement for special compensatory measures. The risk impact is in the "very low" category (i.e., Region III) of the Regulatory Guide 1.174 guidelines for CDF and for LERF.

The EPU is estimated to increase the Grand Gulf internal events PRA CDF to 2.91E-6/rx-yr, an increase of ~8.6%. In addition a full level 2 model was created which reflects EPU conditions [E.1-4]. In this model, LERF increased to 1.48E-07/rx-yr, an increase of ~3%.

The following table shows the changes in contribution to CDF per initiator group for each model revision.

Contribution to CDF Changes in PRA Models				
Contributing Initiator Group	**R1**	**R2**	**R3**	**R3 EPU**
LOSP	42.5%	38.6%	38.7%	39.5%
Loss of Feedwater (FW)	4.3%	21.2%	8.6%	8.1%
PCS Avail Trans	5.9%	16.1%	20.8%	20.5%
Loss of PCS	7.7%	12.1%	12.9%	12.4%
Special(1)	30.6%	11.3%	7.9%	7.8%
LOCA	7.9%	0.4%	4.0%	3.8%
SORV	0.1%	0.1%	0.3%	0.3%
ISLOCA	not modeled	0.1%	0.0%	0.0%
Flood	1.0%	0.1%	0.1%	0.0%

Contribution to CDF Changes in PRA Models (Continued)				
Contributing Initiator Group	**R1**	**R2**	**R3**	**R3 EPU**
RPV Rupture	not modeled	not modeled	0.4%	0.3%
Loss of Service Transformer	not modeled	not modeled	6.5%	7.1%

1. Special initiators include loss of AC bus, DC bus, service water, closed cooling water, or instrument air.

E.1.4.5 PSA Model Peer Review

The 1997 (Rev. 1) Level 1 and LERF model was peer reviewed prior to the 2002 PRA Revision 2 using Boiling Water Reactor (BWR) Owners Group (BWROG) process. The review team used the "BWROG PSA Peer Review Certification Implementation Guidelines," Revision 3, January 1997. Facts and Observation sheets documented the certification team's insights and potential level of significance. All of the 'A' priority PRA peer review comments have been addressed and incorporated into the GGNS PRA model as appropriate. All of the 'B' priority comments have been addressed except for one documentation item related to the internal flood modeling.

Following the Integration and Quantification Task of the Rev. 2 and Rev. 3 model updates, an expert panel of GGNS personnel met to review model quantification results (top 100 cutsets). Various departments (Training, Operations, Engineering and Nuclear Safety) within the GGNS organization were invited to participate. Each of the top 100 cutsets was reviewed individually. In addition, cutsets from accident sequences representing approximately 99 percent of the total core damage frequency were also reviewed if there were no cutsets from these sequences in the top 100. The focus of the review was to identify poor assumptions, over-simplifications, incorrect credit for human actions, sequence timing errors, system modeling errors, and incorrect event probabilities. The reviews resulted in modifications to the model and to the credit given for human actions.

As part of the EPU Level 2 PRA model development, an expert panel review of the preliminary cutsets was performed. The expert panel consisted of members of the Entergy PRA staff and the contractor staff who were developing the Level 2 portion of the PRA model. The purpose of this expert panel review was to provide an assessment of a preliminary Level 2 PRA model and its resulting cutsets. This feedback was then used to correct the model and ensure that the final model incorporated the lessons learned from the initial model development.

E.1.5 The MACCS2 Model—Level 3 Analysis

E.1.5.1 Introduction

SAMA evaluation relies on Level 3 PRA results to measure the effects of potential plant modifications. A Level 3 PRA model using version 1.13.1 of the MELCOR Accident

Consequences Code System Version 2 (MACCS2) [E.1-2] was created for GGNS. This model, which requires detailed site-specific meteorological, population, and economic data, estimates the consequences in terms of population dose and offsite economic cost. Risks in terms of population dose risk (PDR) and offsite economic cost risk (OECR) were also estimated in this analysis. Risk is defined as the product of consequence and frequency of an accidental release.

This analysis considers a base case and two sensitivity cases to account for variations in data and assumptions for postulated internal events. The base case uses estimated time and speed for evacuation. Sensitivity case 1 is the base case with delayed evacuation. Sensitivity case 2 is the base case with lower evacuation speed.

PDR was estimated by summing over all releases the product of population dose and frequency for each accidental release. Similarly, OECR was estimated by summing over all releases the product of offsite economic cost and frequency for each accidental release. Offsite economic cost includes costs that could be incurred during the emergency response phase and costs that could be incurred through long-term protective actions.

E.1.5.2 Input

The following sections describe the site-specific input parameters used to obtain the off-site dose and economic impacts for cost-benefit analyses.

E.1.5.2.1 Projected Total Population by Spatial Element

The total population within a 50-mile radius of GGNS was estimated for the year 2044. Areal weighting was used to transfer the 2044 projected total population from source areas (county) to target areas (spatial elements) by converting county population to a density measure (e.g., number of people in county/acre) and multiplying this density by the area that county has in a spatial element. For spatial elements comprised of elements of more than one county, individual county densities were multiplied by areas of each county in a spatial element and summed. For counties with declining populations, the US Census 2000 values were used to provide a conservative estimate. Louisiana and Mississippi state tourism data was used to calculate a transient to permanent population ratio to increase each county's projected population to account for visitors. Total projected population of the 50-mile zone of analysis is 359,039, and the distribution of the 2044 total population is summarized in Table E.1-11.

Table E.1-11
Estimated Population Distribution within a 50-Mile Radius

Wind Direction	0 to 10 miles	11 to 20 miles	21 to 30 miles	31 to 40 miles	41 to 50 miles	Total
N	25	91	659	765	665	2,205
NNE	27	5,447	34,095	4,354	797	44,720
NE	122	1,938	4,538	5,201	3,913	15,712
ENE	252	239	3,495	4,784	70,710	79,480
E	404	656	1,561	4,750	16,603	23,974
ESE	1,320	1,043	354	6,931	10,849	20,497
SE	3,436	1,371	739	3,407	28,418	37,371
SSE	602	1,158	584	3,472	2,668	8,484
S	124	2,353	4,881	1,949	1,383	10,690
SSW	736	1,426	2,445	29,732	4,606	38,945
SW	250	375	1,493	14,646	3,387	20,151
WSW	88	1,740	297	1,781	2,162	6,068
W	103	316	351	4,505	3,080	8,355
WNW	20	2,409	263	4,451	11,260	18,403
NW	12	136	57	2,239	6,332	8,776
NNW	3	94	11,567	714	2,830	15,208
Totals	**7,524**	**20,792**	**67,379**	**93,681**	**169,663**	**359,039**

E.1.5.2.2 Land Fraction

The National Hydrography Dataset for the watersheds within the 50-mile radius area was used to calculate the extent of land and surface water coverage. Calculated values ranged from 0.00 to 1.00. A value of 1.00 indicates the spatial element area is all land, with no significant surface water.

E.1.5.2.3 Watershed Class

Watershed Index is defined by MACCS2 as areas drained by rivers (Class 1) or large water bodies (Class 2). Class 2 is intended only for use with a very large lake, similar in size to Lake Michigan. For GGNS, a watershed index of 1 (drained by rivers) was used for all spatial elements.

E.1.5.2.4 Regional Economic Data

Region Index

Each spatial element was assigned to an economic region, defined in this report as a county. When a spatial element was comprised of more than one county, it was assigned to the county that had the most area in that spatial element. Two parishes in Louisiana (Caldwell and West Carroll) and seven counties in Mississippi (Amite, Madison, Rankin, Sharkey, Simpson, Wilkinson, and Yazoo) were not assigned due to their small representation in any one spatial element.

Regional Economic Data

Economic data was obtained from the US Census of Agriculture (USDA 2007) for 2007, Department of Commerce and Department of Labor Statistics.

VALWF– Value of Farm Wealth

MACCS2 requires an average value of farm wealth (dollars/hectare) for the 50-mile radius area around GGNS. The county-level farmland property value was used as a basis for deriving this value. VALWF is $4,787.34/hectare.

VALWNF– Value of Non-Farm Wealth

MACCS2 also requires an average value of non-farm wealth. The county-level non-farm property value was used as a basis for deriving this value. VALWNF is $97,224.14/person.

Other economic parameters and their values are shown below. The values were calculated using average U.S. Consumer Prices Indices. A proportional factor of 1.9 was developed using the December 1987 CPI (113.6) and the December 2010 CPI (218.056). This CPI factor was applied to the previously recommended values of the following parameters to represent current values.

Variable	Description	Value
CHEVACST001	Daily cost for a person who has been evacuated ($/person-day)	51.3
CHPOPCST001	Population relocation cost ($/person)	9500
CHRELCST001	Daily cost for a person who is relocated ($/person-day)	51.3
CHCDFRM001	Cost of farm decontamination for the various levels of decontamination ($/hectare)	1068.75 2375
CHCDNFRM001	Cost of non-farm decontamination for the various levels of decontamination ($/person)	5700 15200
CHDLBCST001	Average cost of decontamination labor ($/person-year)	66500
DPRATE	Property depreciation rate (per year)	0.2
DSRATE	Investment rate of return (per year)	0.12

E.1.5.2.5 Agriculture Data

The source of regional crop information is the 2007 United States Census of Agriculture. The crops listed for each county within the 50-mile area were summed and mapped into the seven MACCS2 crop categories.

E.1.5.2.6 Meteorological Data

The MACCS2 model requires meteorological data for wind speed, wind direction, atmospheric stability, accumulated precipitation, and atmospheric mixing heights. The required data was obtained from the GGNS meteorological monitoring system and regional National Weather Service stations.

Site-Specific Data

Meteorological data collected at the site from calendar years 2005 through 2009 were compiled for the MACCS2 input file. Missing data for parameters of interest were estimated using data substitution methods. These methods include substitution of missing data with valid data from the previous hour and substitution of valid data collected from other elevations on the meteorological tower. The 2009 data resulted in the highest release quantities and was therefore used to perform the base case analysis and sensitivity cases.

Regional Mixing Height Data

Mixing height is defined as the height of the atmosphere above ground level within which a released contaminant will become mixed (from turbulence) within approximately one hour. GGNS mixing height data were estimated using the ground level and upper-air data from the National Weather Service.

E.1.5.2.7 Emergency Response Assumptions

A detailed analysis of evacuation scenarios in the 10-mile emergency planning zone (EPZ) were addressed in the GGNS evacuation travel time estimate study for both the Mississippi side (Claiborne and Warren counties) and the Louisiana side (Tensas Parish) of the Mississippi River [E.1-3]. These studies, conducted from August through December 2006, provide an analysis of the range and variation of public reaction to the evacuation notification process. This is the most recent report available and is still valid because the population in the two counties and a parish with land in the 10-mile EPZ has been in decline since the studies were conducted.

Evacuation Delay Time

The estimates for the general public were based on the following evacuation components: notification, preparation to depart, and actual evacuation. The evacuation study concluded that 100 percent of the general public would be prepared to begin an evacuation within 195 minutes from activation of the evacuation notification process. This includes 50 minutes for notification and 145 minutes for the population to get ready to leave, for a total delay time of 195 minutes.

Evacuation Speed

The evacuation travel time studies concluded that in the worst case the general public within the 10-mile EPZ could be evacuated in 4 hours and 10 minutes (250 minutes) from issuance of an order to evacuate for 100 percent of the population. Total evacuation time includes the delay time discussed above. Since 195 minutes of this is the delay time, the worst case transit time is 55 minutes. The longest travel times were required for evacuation scenarios occurring on mid-week days in adverse weather (rain).

Evacuation travel speed is calculated by dividing the distance traveled by the time required to evacuate 100 percent of the total population. Since the maximum travel distance out of the EPZ is 10 miles, the general public transit speed is 10 mi / 55 min = 10.9 mph (4.87m/s).

E.1.5.2.8 Core Inventory

The GGNS core inventory is shown in Table E.1-12. These values are based on ORIGEN 2.1 evaluations supporting the EPU to 115% (4408 MWt) of the original licensed thermal power.

Table E.1-12
Estimated GGNS Core Inventory (Becquerels)(1)

Nuclide	Inventory	Nuclide	Inventory
Co-58	4.22E+16	Te-131m	6.59E+17
Co-60	7.29E+16	Te-132	6.40E+18
Kr-85	5.81E+16	I-131	4.51E+18
Kr-85m	1.19E+18	I-132	6.51E+18
Kr-87	2.28E+18	I-133	9.18E+18
Kr-88	3.20E+18	I-134	1.01E+19
Rb-86	1.12E+16	I-135	8.58E+18
Sr-89	4.33E+18	Xe-133	8.81E+18
Sr-90	4.63E+17	Xe-135	3.12E+18
Sr-91	5.40E+18	Cs-134	1.04E+18
Sr-92	5.85E+18	Cs-136	3.35E+17
Y-90	4.92E+17	Cs-137	6.18E+17
Y-91	5.59E+18	Ba-139	8.18E+18
Y-92	5.88E+18	Ba-140	7.92E+18
Y-93	6.77E+18	La-140	8.40E+18
Zr-95	7.99E+18	La-141	7.47E+18
Zr-97	8.25E+18	La-142	7.22E+18
Nb-95	8.03E+18	Ce-141	7.51E+18
Mo-99	8.55E+18	Ce-143	6.96E+18
Tc-99m	7.44E+18	Ce-144	6.14E+18
Ru-103	7.14E+18	Pr-143	6.73E+18
Ru-105	5.03E+18	Nd-147	3.00E+18
Ru-106	2.76E+18	Np-239	9.32E+19
Rh-105	4.74E+18	Pu-238	1.89E+16
Sb-127	5.00E+17	Pu-239	1.91E+15
Sb-129	1.48E+18	Pu-240	2.58E+15

Table E.1-12 (Continued)
Estimated GGNS Core Inventory (Becquerels)(1)

Nuclide	Inventory	Nuclide	Inventory
Te-127	4.96E+17	Pu-241	8.44E+17
Te-127m	6.70E+16	Am-241	9.44E+14
Te-129	1.45E+18	Cm-242	2.50E+17
Te-129m	2.16E+17	Cm-244	1.58E+16

1. From GGNS specific data for a power level of 4408 MWth [E.1-2].

E.1.5.2.9 Source Terms

Eleven release categories, corresponding to internal event sequences, were part of the MACCS2 input. Section E.1.2.2.6 provides details of the source terms for postulated internal events. A linear release rate was assumed between the time the release started and the time the release ended.

E.1.5.3 RESULTS

Risk estimates for one base case and two sensitivity cases were analyzed with MACCS2. Sensitivity Case 1 assumes an evacuation time delay that is increased from 3.25 hours (base) to 6.5 hours. Sensitivity Case 2 assumes a lower average evacuation speed; the speed was reduced from 4.87 m/s (base) to 2.435 m/s.

Table E.1-13 shows estimated base case mean risk values for each release mode. The estimated mean values of PDR and offsite OECR for GGNS are 0.486 person-rem/yr and $1,244/yr, respectively.

Table E.1-13
Base Case Mean PDR and OECR Values for Postulated Internal Events

Characteristics of Release Mode[(1)]		Population Dose		Offsite Economic Cost	Population Dose Risk (PDR)	Offsite Economic Cost Risk (OECR)
ID	Frequency (per year)	(person-sv)[(1)]	person-rem	($)	(person-rem/yr)[(2)]	$/yr
H/L	8.73E-08	4.12E+03	4.12E+05	1.04E+09	3.60E-02	9.08E+01
H/E	1.05E-07	2.29E+03	2.29E+05	3.13E+08	2.41E-02	3.29E+01
H/I	1.23E-08	5.10E+03	5.10E+05	1.37E+09	6.26E-03	1.68E+01
M/E	3.49E-07	4.66E+03	4.66E+05	1.31E+09	1.63E-01	4.57E+02
M/I	1.73E-07	6.70E+03	6.70E+05	1.81E+09	1.16E-01	3.14E+02
M/L	2.71E-07	3.86E+03	3.86E+05	1.04E+09	1.05E-01	2.82E+02
L/E	4.04E-09	9.92E+02	9.92E+04	7.32E+07	4.00E-04	2.95E-01
L/I	3.34E-08	3.26E+03	3.26E+05	7.48E+08	1.09E-02	2.50E+01
L/L	1.32E-07	1.75E+03	1.75E+05	1.66E+08	2.30E-02	2.18E+01
LL/E	2.00E-09	3.62E+00	3.62E+02	4.63E+05	7.24E-07	9.26E-04
LL/I	2.11E-09	1.80E+00	1.80E+02	4.59E+05	3.80E-07	9.68E-04
LL/L	6.83E-09	2.90E+03	2.90E+05	4.81E+08	1.98E-03	3.28E+00
				Totals	**4.86E-01**	**1.24E+03**

1. Conversion Factor: 1 sv = 100 rem.
2. Value is the product of the release mode frequency and the population dose.

Results of sensitivity analyses indicate that a delayed evacuation or a lower evacuation speed would not have any significant effects on the offsite consequences or risks determined in this study. Table E.1-14 summarizes offsite consequences in terms of population dose (person-sv) and offsite economic cost ($) for the base case and the sensitivity cases. Comparison of the consequences indicates a deviation of less than 1% between the base case and the sensitivity case results.

Table E.1-14
Summary of Offsite Consequence Results for Sensitivity Results

	Population Dose (person-sv)[(1)]			Offsite Economic Cost ($)		
Release Mode	**Base**	**Longer Time for Evacuation**	**Slower Speed of Evacuation**	**Base**	**Longer Time for Evacuation**	**Slower Speed of Evacuation**
H/L	4.12E+03	4.12E+03	4.12E+03	1.04E+09	1.04E+09	1.04E+09
H/E	2.29E+03	2.30E+03	2.29E+03	3.13E+08	3.13E+08	3.13E+08
H/I	5.10E+03	5.10E+03	5.10E+03	1.37E+09	1.37E+09	1.37E+09
M/E	4.66E+03	4.66E+03	4.66E+03	1.31E+09	1.31E+09	1.31E+09
M/I	6.70E+03	6.70E+03	6.70E+03	1.81E+09	1.81E+09	1.81E+09
M/L	3.86E+03	3.86E+03	3.86E+03	1.04E+09	1.04E+09	1.04E+09
L/E	9.92E+02	9.93E+02	9.96E+02	7.32E+07	7.32E+07	7.32E+07
L/I	3.26E+03	3.27E+03	3.26E+03	7.48E+08	7.48E+08	7.48E+08
L/L	1.75E+03	1.75E+03	1.75E+03	1.66E+08	1.66E+08	1.66E+08
LL/E	3.62E+00	3.65E+00	3.63E+00	4.63E+05	4.63E+05	4.63E+05
LL/I	1.80E+00	1.83E+00	1.80E+00	4.59E+05	4.59E+05	4.59E+05
LL/L	2.90E+03	2.90E+03	2.90E+03	4.81E+08	4.81E+08	4.81E+08
Total	**4.86E-01**	**4.86E-01**	**4.86E-01**	**1.24E+03**	**1.24E+03**	**1.24E+03**
	person-rem/yr	person-rem/yr	person-rem/yr	$/yr	$/yr	$/yr

1. Conversion Factor: 1 sv = 100 rem.

E.1.6 References

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ATTACHMENT E.2

EVALUATION OF GGNS SAMA CANDIDATES

E.2 EVALUATION OF GGNS SAMA CANDIDATES

This section describes the generation of the initial list of potential SAMA candidates, screening methods, and the analysis of the remaining SAMA candidates.

E.2.1 SAMA List Compilation

Candidate SAMAs are defined as potential enhancements to the plant design, operating procedures, inspection programs, or maintenance programs that have the potential to reduce the severe accident risk of GGNS. These SAMAs can be characterized as either hardware (i.e., physical modification of plant structure, systems, and components) or non-hardware enhancements (i.e., operation, maintenance programs, and procedure changes), or a combination of the two. The candidate SAMAs considered for GGNS encompass both hardware and non-hardware enhancements.

A list of SAMA candidates was developed by reviewing industry documents and considering other plant-specific enhancements not identified in published industry documents. Since GGNS is a BWR, considerable attention was paid to the SAMA candidates from SAMA analyses for other BWR plants. Industry documents reviewed include the following.

- NEI 05-01, Severe Accident Mitigation Alternatives Analysis [E.2-1]
- James A. FitzPatrick Nuclear Power Plant SAMA Analysis [E.2-2]
- Vermont Yankee Nuclear Power Station SAMA Analysis [E.2-3]
- Pilgrim Nuclear Power Station SAMA Analysis [E.2-4]
- Oyster Creek Nuclear Generating Station SAMA Analysis [E.2-5]
- Monticello Nuclear Generating Plant SAMA Analysis [E.2-6]
- Brunswick Steam Electric Plant, Units 1 and 2 SAMA Analysis [E.2-7]
- NUREG-1742, *Perspectives Gained from the Individual Plant Examination of External Events (IPEEE) Program* [E.2-8]
- Duane Arnold Energy Center [E.2-11]
- Susquehanna Steam Electric Station, Units 1 and 2 [E.2-10]
- Cooper Nuclear Station, Unit 1 [E.2-9]

In addition to SAMA candidates from review of industry documents, additional SAMA candidates were obtained from plant-specific sources, such as the GGNS IPE [E.2-18] and the GGNS IPEEE [E.2-13, E.2-14, E.2-15, E.2-16, E.2-17]. In the IPE and IPEEE several enhancements related to severe accident insights were recommended and implemented. These enhancements are included in the comprehensive list of Phase I SAMA candidates as 226 through 245 (see Table E.2-1). The current GGNS PSA levels1 and 2 models were also used to identify plant-specific modifications for inclusion in the comprehensive list of SAMA candidates. The risk significant events from the current PSA model were reviewed for similar failure modes and effects that could be addressed through a potential enhancement to the plant. The correlation between SAMAs and the risk significant terms are listed in Tables E.1-2 and E.1-4.

The comprehensive list of 249 candidate SAMAs considered for implementation at GGNS is provided in onsite documentation [E.2-21].

E.2.2 Qualitative Screening of SAMA Candidates (Phase I)

The purpose of the preliminary SAMA screening was to eliminate from further consideration enhancements that were not viable for implementation at GGNS. Potential SAMA candidates were screened out if they modified features not applicable to GGNS, if they had already been implemented at GGNS, or if they were similar in nature and could be combined with another SAMA candidate to develop a more comprehensive or plant-specific SAMA candidate. During this process, 60 of the Phase I SAMA candidates were screened out because they were not applicable to GGNS, 28 of the Phase I SAMA candidates were screened out because they were similar in nature and could be combined with another SAMA candidate, and 98 of the Phase I SAMA candidates were screened out because they had already been implemented at GGNS, leaving 63 SAMA candidates for further analysis. The final screening process involved identifying and eliminating those items whose implementation cost would exceed their benefit as described below. Table E.2-2 provides a description of each of the 63 Phase II SAMA candidates.

E.2.3 Final Screening and Cost Benefit Evaluation of SAMA Candidates (Phase II)

A cost/benefit analysis was performed on each of the remaining SAMA candidates. If the implementation cost of a SAMA candidate was determined to be greater than the potential benefit (i.e., there was a negative net value) the SAMA candidate was considered not to be cost beneficial and was not retained as a potential enhancement.

The expected cost of implementation of each SAMA was established from existing estimates of similar modifications. Most of the cost estimates were developed from similar modifications considered in previously performed SAMAs. In particular, these cost-estimates were derived from the following sources.

- Pilgrim Nuclear Power Station [E.2-4]
- Hope Creek [E.2-12]
- Columbia Generating Station [E.2-19]
- Cooper Nuclear Station [E.2-9]
- Duane Arnold Energy Center [E.2-11]

The benefit of implementing a SAMA candidate was estimated in terms of averted consequences by altering the base case PSA model to reflect the maximum benefit of the improvement and re-quantifying the PDS frequency with a truncation of 1E-12. The benefit was estimated by calculating the arithmetic difference between the total estimated costs associated with the four impact areas for the baseline plant design and the total estimated impact area costs for the enhanced plant design (following implementation of the SAMA candidate).

Values for avoided public and occupational health risk were converted to a monetary equivalent (dollars) via application of the *Regulatory Analysis Technical Evaluation Handbook* [E.2-20] conversion factor of $2,000 per person-rem and discounted to present value. Values for avoided off-site economic costs were also discounted to present value.

As this analysis focuses on establishing the economic viability of potential plant enhancement when compared to attainable benefit, detailed cost estimates often were not required to make informed decisions regarding the economic viability of a particular modification. The implementation costs for several of the SAMA candidates were clearly in excess of the attainable benefit estimated from a particular analysis case. Nonetheless, the cost of each SAMA candidate was conceptually estimated to the point where conclusions regarding the economic viability of the proposed modification could be adequately gauged.

Based on a review of previous SAMA evaluations and an evaluation of expected implementation costs at GGNS, the following estimated cost ranges for each type of proposed SAMA implementation were used.

Type of Change	Estimated Cost Range
Procedural only	\$25K–\$50K
Procedural change with engineering or training required	\$50K–\$200K
Procedural change with engineering and testing/ training required	\$200K–\$300K
Hardware modification	\$100K to > \$1000K

Detailed cost estimates were based on the engineering judgment of project engineers experienced in performing design changes at the facility. The detailed cost estimates considered engineering, labor, materials, and support functions such as planning, scheduling, health physics, quality assurance, security, safety, and firewatch. The estimates included a 20% contingency on the design and installation costs but did not account for inflation, replacement power during extended outages necessary for SAMA implementation, or increased maintenance or operation costs following SAMA implementation. The cost benefit comparison and disposition of each of the 63 Phase II SAMA candidates is presented in Table E.2-2.

Bounding evaluations (or analysis cases) were performed to address specific SAMA candidates or groups of similar SAMA candidates. These analysis cases overestimated the benefit and thus were conservative calculations. For example, one SAMA candidate suggested installing digital large break LOCA protection; the bounding calculation estimated the benefit of this improvement by total elimination of risk due to large break LOCA (see analysis of Phase II SAMA 56 in Table E.2-2). This calculation obviously overestimated the benefit, but if the inflated benefit indicated that the SAMA candidate was not cost beneficial, then the purpose of the analysis was satisfied.

A description of the analysis cases used in the evaluation follows.

Case 1: DC Power

This analysis case was used to evaluate the change in plant risk from provide additional DC battery capacity. A bounding analysis was performed by eliminating station blackout cutsets from the PSA model [basic events ZSBO and ZT1B were set to zero], which resulted in an internal and external benefit (with uncertainty) of approximately $346,968. This analysis case was used to model the benefit of Phase II SAMAs 1, 2, 11, 12, and 15.

Case 2: Improve Charger Reliability

This SAMA analysis case was used to evaluate the change in plant risk from improving the diversity of the DC battery charging capability by adding an additional battery charger or providing a means to lower battery charger failure. A bounding analysis was performed by setting the failure of chargers contribution to zero in the level 1 PSA model. The following basic events were removed from the model:

11DA-007-D	11DA-008-D	11DB-007-E	11DB-008-E
11DC-007-F	11DC-008-F	11DD-007-X	11DD-008-X
11DE-007-X	11DE-008-X	L21-CO-CB11A02-D	L21-CO-CB11A03-D
L21-CO-CB11B02-E	L21-CO-CB11B03-E	L21-CO-CB11D02-X	L21-CO-CB11D03-X
L21-CO-CB11E02-X	L21-CO-CB11E03-X	L51-LP-BC-1A4-D	L51-LP-BC-1A5-D
L51-LP-BC-1B4-E	L51-LP-BC-1B5-E	L51-LP-BC-1D4-X	L51-LP-BC-1D5-X
L51-LP-BC-1E4-X	L51-LP-BC-1E5-X	L51-MA-BC-1A4-D	L51-MA-BC-1A5-D
L51-MA-BC-1B4-E	L51-MA-BC-1B5-E	L51-MA-BC-1D4-X	L51-MA-BC-1D5-X
L51-MA-BC-1E4-X	L51-MA-BC-1E5-X	P81-CO-CB11C02-F	P81-CO-CB11C03-F
P81-CO-CB70104-F	P81-FO-HE1C5-F	P81-LP-BC-1C4-F	P81-LP-BC-1C5-F
P81-MA-BC-1C4-F	P81-MA-BC-1C5-F	R20-CF-CB-BKR	R20-CO-CB15102-X
R20-CO-CB15202-X	R20-CO-CB15306-D	R20-CO-CB15602-D	R20-CO-CB16102-X
R20-CO-CB16202-X	R20-CO-CB16306-E	R20-CO-CB16602-E	R20-CO-CB31116-F

This resulted in an internal and external benefit (with uncertainty) of approximately $40,793. This analysis case was used to model the benefit of Phase II SAMAs 3 and 13.

Case 3: Add DC System Cross-Ties

This analysis case was used to evaluate the change in plant risk from providing DC bus cross-ties. A bounding analysis was performed by eliminating failure of DC power gates in the PSA model (with the following gates removed from the model: 11DA-001, 11DA-001-SBO, 11DA-001T, 11DA-001X, 11DA-001Y, 11DA-001Z, 11DB-001, 11DB-001-SBO, 11DB-001T, 11DB-001X, and 11DB-001Z), which resulted in an internal and external benefit (with uncertainty) of approximately $219,169. This analysis case was used to model the benefit of Phase II SAMA 4.

Case 4: Increase Availability of On-Site AC Power

This analysis case was used to evaluate the change in plant risk from improving the backup sources for the Vital AC buses 15AA, 16AB, and 17AC. A bounding analysis was performed by eliminating failure of DG11, DG12, and DG13 to their AC buses (15AA, 16AB, and 17AC, respectively) in the Level 1 model (with the following gates set to zero: DG11-001L, DG11-001T, DG11-001X, DG11-001X-HPCS, DG11-001X-ONSP, DG11-001XP, DG11-001XZ, DG12-001L, DG12-001T, DG12-001X, DG12-001XP, DG12-001XZ, DG13-001N, DG13-001X, DG11-06, DG12-06, SBO1-DG13-001X, and SBO2-DG13-001X), which resulted in an internal and external benefit (with uncertainty) of approximately $448,189. This analysis case was used to model the benefit of Phase II SAMAs 5 and 8.

Case 5: Improve AC Power

This analysis case was used to evaluate the change in plant risk from improving the 4.16-kV bus cross-tie ability. A bounding analysis was performed by eliminating the loss of the 4.16-kV buses in the PSA model [with the following gates removed from the model: 15AA-001, 15AA-001D, 15AA-001-HPCS, 15AA-001L, 15AA-001P, 15AA-001T, 15AA-001U, 15AA-001Z, 16AB-001, 16AB-001D, 16AB-001-HPCS, 16AB-001L, 16AB-001ONSP, 16AB-001P, 16AB-001T, 16AB-001U, 16AB-001Z, 17AC-001, 17AC-001-DGX, and 17AC-001N], which resulted in an internal and external benefit (with uncertainty) of approximately $532,571. This analysis case was used to model the benefit of Phase II SAMAs 6 and 17.

Case 6: Reduce Loss of Off-Site Power During Severe Weather

This SAMA analysis evaluated the change in plant risk from installing an additional buried off-site power source. A bounding analysis was performed by removing LOSP due to severe weather from the LOSP initiating event frequencies [%T1 and %T1P were multiplied by 19/24]. This resulted in an internal and external benefit (with uncertainty) of approximately $78,261. This analysis case was used to model the benefit of Phase II SAMA 7.

Case 7: Provide Backup Emergency Diesel Generator (EDG) Cooling

This analysis case was used to evaluate the change in plant risk from increasing EDG reliability by adding a backup source of diesel cooling. A bounding analysis was performed by eliminating failure of SW cooling to the EDGs [the following gates were eliminated: DGA-001L, DGA-001T, DGA-001X, DGA-001X-HPCS, DGA-001X-ONSP, DGA-001XP, DGA-001XZ, DGB-001L, DGB-001T, DGB-001X, DGB-001XP, DGB-001XZ, DGC-001N, and DGC-001X], which resulted in an internal and external benefit (with uncertainty) of approximately $49,545. This analysis case was used to model the benefit of Phase II SAMAs 9 and 10.

Case 8: Increase EDG Reliability

This analysis case was used to evaluate the change in plant risk from providing a portable EDG fuel oil transfer pump. A bounding analysis was performed by eliminating failure of EDGs to run in the PSA model [the following basic events ere set to zero: P75-FR-DG-DG11-A, P75-FR-DG-

DG12-B, P75-CF-3DGR-Z, and P75-CF-DGR-Z], which resulted in an internal and external benefit (with uncertainty) of approximately $91,044. This analysis case was used to model the benefit of Phase II SAMA 14.

Case 9: Improve DG reliability

This analysis case was used to evaluate the change in plant risk from providing a diverse swing diesel generator air start compressor. A bounding analysis was performed by eliminating the common cause failure (CCF) contribution of failure to start EDGs in the PSA model [the following CCF events were set to zero: P75-CF-3DGS-Z and P75-CF-DGS-Z], which resulted in an internal and external benefit (with uncertainty) of approximately $6,542. This analysis case was used to model the benefit of Phase II SAMA 16.

Case 10: Reduce Plant-Centered Loss of Off-Site Power

This analysis case was used to evaluate the change in plant risk from protecting transformers from failure. A bounding analysis was performed by removing the initiating contribution of plant and switchyard centered events in the PSA model. The LOSP notebook does not discriminate transformer failures between switchyard-centered or plant-centered so all plant-centered and switchyard-centered LOSP events were removed from the LOSP frequency [%T1 and %T1P were multiplied by 9/24], which resulted in an internal and external benefit (with uncertainty) of approximately $229,668. This analysis case was used to model the benefit of Phase II SAMA 18.

Case 11: Redundant Power to Torus Hard Pipe Vent (THPV) Valves

This analysis case was used to evaluate the change in plant risk from providing redundant power to the direct torus vent valves. A bounding analysis was performed by eliminating failure of power to containment vents in the PSA model, which resulted in an internal and external benefit (with uncertainty) of approximately $32,297. This analysis case was used to model the benefit of Phase II SAMA 19.

Specifically, the following gates were set to zero or removed:

- 15P21-001 PROB 0
- 16P41-001 PROB 0
- 1DA1-001 deleted from M41-002, M41-002X, and VC-L2-AC-POWER
- 1DB1-001 deleted from M41-002, M41-002X, and VC-L2-AC-POWER

Case 12: High Pressure Injection System

This analysis case evaluated the change in plant risk from plant modifications that would increase the availability of high pressure core spray (installing a high pressure injection system independent of AC power or a passive high pressure core injection system). A bounding analysis was performed by eliminating failure of HPCS in the PSA model [gates U1, U1-RX, and U1-SI were removed from the model], which resulted in an internal and external benefit (with uncertainty) of approximately $1,784,736. This analysis case was used to model the benefit of Phase II SAMAs 20 and 61.

Case 13: Extend RCIC Operation

This analysis case was used to evaluate the change in plant risk from raising the RCIC back pressure trip setpoint. A bounding analysis was performed by eliminating failure of trip due to pressure in the PSA model [gate E51-400 was set to zero], which resulted in an internal and external benefit (with uncertainty) of approximately $30,093. This analysis case was used to model the benefit of Phase II SAMA 21.

Case 14: Improve ADS System

This analysis case was used to evaluate the change in plant risk from modifying the automatic depressurization system (ADS) components to improve reliability by adding larger accumulators. A bounding analysis was performed by eliminating failure of ADS valves in the PSA model [gates B21-001B1 and B21-003 were set to zero], which resulted in an internal and external benefit (with uncertainty) of approximately $897,317. This analysis case was used to model the benefit of Phase II SAMA 22.

Case 15: Improve ADS Signals

This analysis case was used to evaluate the change in plant risk from adding signals to open safety relief valves automatically in an MSIV closure transient. A bounding analysis was performed by eliminating failure of the SRV to open in the PSA model [the following gates were set to zero: OP-DEPRESS-OP1, B21-001B1, B21-001A, B21-006 and basic event B21-CF-SF-K], which resulted in an internal and external benefit (with uncertainty) of approximately $388,150. This analysis case was used to model the benefit of Phase II SAMA 23.

Case 16: Low Pressure Injection System

This analysis case was used to evaluate the change in plant risk from adding a diverse low pressure injection system. A bounding analysis was performed by eliminating failure of LPCI and low pressure core spray (LPCS) in the PSA model [the following gates were set to zero: V2, V2-RX, V2-SI, V3, V3-RX, V3-SI, and V3-SBO], which resulted in an internal and external benefit (with uncertainty) of approximately $689,896. This analysis case was used to model the benefit of Phase II SAMA 24.

Case 17: Emergency Core Cooling System (ECCS) Low Pressure Interlock

This analysis case was used to evaluate the change in plant risk from installing a bypass switch to allow operators to bypass the low reactor pressure interlock circuitry that inhibits opening the LPCI or core spray injection valves following sensor or logic failures that prevent all low pressure injection valves from opening. A bounding analysis was performed by eliminating ECCS permissives and interlock failure in the PSA model [the following gates were set to zero: E12-110, E12-190, B21-012A, B21-013A, B21-026A, and B21-027A], which resulted in an internal and external benefit (with uncertainty) of approximately $30,093. This analysis case was used to model the benefit of Phase II SAMA 25.

Case 18: RHR Heat Exchangers

This analysis case was used to evaluate the change in plant risk from implementing modifications to allow manual alignment of the fire water system to RHR heat exchangers. A bounding analysis was performed by eliminating failure of SSW to provide cooling to the RHR heat exchangers [the following gates were removed from the model: P41-RHRHXA-SBO, P41-RHRHXB-SBO, P41-RHRHXA and P41-RHRHXB], which resulted in an internal and external benefit (with uncertainty) of approximately $615,669. This analysis case was used to model the benefit of Phase II SAMA 26.

Case 19: Emergency Service Water System Reliability

This analysis case was used to evaluate the change in plant risk from installing an additional service water pump. A bounding analysis was performed by eliminating failure of service water pumps in the PSA model [the following basic events were set to zero: P41-CF-MCP001R-R, P41-CF-MCP001S-R, P41-CF-MVDISNA-R, P41-CF-MVDISNB-R, P41-CF-MVDISNC-R, P41-CF-MVF001AB, P41-CF-MV-F001AB, P41-CF-MVF005AB, and P41-CF-ST-SUCT-R], which resulted in an internal and external benefit (with uncertainty) of approximately $113,708. This analysis case was used to model the benefit of Phase II SAMA 27.

Case 20: Main Feedwater System Reliability

This analysis case was used to evaluate the change in plant risk from installing a motor-driven feedwater pump. A bounding analysis was performed by setting failure to inject from feedwater to zero in the PSA model [gate N21-002 was set to zero], which resulted in an internal and external benefit (with uncertainty) of approximately $486,149. This analysis case was used to model the benefit of Phase II SAMA 28.

Case 21: Increase Availability of Room Cooling

This analysis case was used to evaluate the change in plant risk from providing a redundant HVAC train to rooms dependent on room cooling. A bounding analysis was performed by eliminating failure of room cooling to the safeguard switchgear battery rooms, standby service water pump rooms, LPCS pump rooms, and HPCS pump rooms in the PSA model [the following gates were set to zero: T51-060, Z77-300, T51-080, HVC-1000XP, HVC-1000XZ, HVC-1000-HPCS, HVC-1000X-HPCS, HVC-1000X-ONSP, HVC-1000X-SBO, and HVC-2000X], which resulted in an internal and external benefit (with uncertainty) of approximately $526,200. This analysis case was used to model the benefit of Phase II SAMA 29.

Case 22: Increase Availability of the DG System through HVAC Improvements

This analysis case was used to evaluate the change in plant risk from enhancing diesel generator room cooling. A bounding analysis was performed by eliminating failure of cooling of three diesel generator rooms in the PSA model [gates HVC-001X, HVC-010X, and HVC-020X were set to zero]. This resulted in an internal and external benefit (with uncertainty) of approximately $227,963. This analysis case was used to model the benefit of Phase II SAMAs 30, 32, and 33.

Case 23: Increase Reliability of HPCI and RCIC Room Cooling

This analysis case was used to evaluate the change in plant risk from creating the ability to switch HPCI and RCIC room fan power supply to DC in an SBO event. Since RCIC pump continued operation is not dependent on room cooling, a bounding analysis was performed by eliminating failure of power to the HPCS pump room cooler in the PSA model [gate 17B01-001 was removed from gate T51-080], which resulted in an internal and external benefit (with uncertainty) of approximately $30,093. This analysis case was used to model the benefit of Phase II SAMA 31.

Case 24: Increase Reliability of Instrument Air

This analysis case was used to evaluate the change in plant risk from improving the reliability of the instrument air system. A bounding analysis was performed by eliminating failure of the instrument air system in the level 1 PSA model [the following gates were set to zero: P53-001, P53-001AX, P53-001X, P53-101, P53-001A, P53-101X, P53-102, P53-102X, and initiator %TIA], which resulted in an internal and external benefit (with uncertainty) of approximately $413,527. This analysis case was used to model the benefit of Phase II SAMAs 34 and 35.

Case 25: Backup Nitrogen to SRV

This analysis case was used to evaluate the change in plant risk from installing permanent nitrogen bottles as backup gas supply. A bounding analysis was performed by eliminating operator failure to install bottles in the PSA model [basic event B21-FO-HEBOTTLES was set to zero], which resulted in an internal and external benefit (with uncertainty) of approximately $121,841. This analysis case was used to model the benefit of Phase II SAMA 36.

Case 26: Improve Availability of SRVs and MSIVs

This analysis case was used to evaluate the change in plant risk from improving SRV and MSIV pneumatic components. A bounding analysis was performed by eliminating failure of non-ADS SRVs in the PSA model [gate B21-004 and basic events B21-FO-HEDEP2-I and B21-CF-SF-K were set to zero], which resulted in an internal and external benefit (with uncertainty) of approximately $901,893. This analysis case was used to model the benefit of Phase II SAMA 37.

Case 27: Improve Suppression Pool Cooling

This analysis case was used to evaluate the change in plant risk from installing an independent method of suppression pool cooling. This would allow the suppression pool to be an alternate cooling source for the RHR heat exchanger. A bounding analysis was performed by eliminating the failure of flow to the RHR heat exchangers in the PSA model [gates P41-RHRHXA, P41-RHRHXB, P41-RHRHXA-SBO, and P41-RHRHXB-SBO were removed from the model], which resulted in an internal and external benefit (with uncertainty) of approximately $615,669. This analysis case was used to model the benefit of Phase II SAMA 38.

Case 28: Increase Availability of Containment Heat Removal

This analysis case was used to evaluate the change in plant risk from increasing the availability of containment heat removal. A bounding analysis was performed by eliminating failure of cooled flow through the injection line in the PSA model [gates E12-686, E12-686X, E12-686Y, E12-686Y-SBO, E12-686-SBO, E12-686X-SBO, E12-665, E12-665-SBO, E12-620, E12-620X, E12-620Y, E12-620-SBO, E12-620X-SBO, E12-620Y-SBO, E12-604, and E12-604-SBO were set to zero], which resulted in an internal and external benefit (with uncertainty) of approximately $865,312. This is similar to analysis case 29; however, the containment spray injection valves are not set to zero. This analysis case was used to model the benefit of Phase II SAMAs 39 and 41.

Case 29. Decay Heat Removal Capability—Drywell Spray

This analysis case was used to evaluate the change in plant risk from improving drywell spray capability by installing a passive drywell spray system. Enhancements of decay heat removal capability decrease the probability of loss of containment heat removal. A bounding analysis was performed by setting the events for loss of RHR spray to zero in the PSA model [the following gates were set to zero: W3, W3X, #W3X, W3-SBO, W3X-SBO, W3Y, and W3Y-SBO], which resulted in an internal and external benefit (with uncertainty) of approximately $865,649. This analysis case was used to model the benefit of Phase II SAMA 40.

Case 30: Increase Availability of the CST

This analysis case was used to evaluate the change in plant risk from providing a means of replenishing CST water from the firewater, demineralized water, or service water system. A bounding analysis was performed by eliminating the CDF contribution from HPCS and RCIC suction [gates P11-F021 and E22-041 were set to zero], which resulted in an internal and external benefit (with uncertainty) of approximately $323,696. This analysis case was used to model the benefit of Phase II SAMA 42.

Case 31: Filtered Vent to Increase Heat Removal Capacity for Non-ATWS Events

This analysis case was used to evaluate the change in plant risk from installing a filtered containment vent. A bounding analysis was performed by reducing the baseline accident progression source terms by a factor of 2 (excluding noble gases) to reflect the additional filtered capability. Reducing the releases from the vent path resulted in an internal and external benefit (with uncertainty) of approximately $242,759. This analysis case was used to model the benefit of Phase II SAMA 43.

Case 32: Reduce Hydrogen Ignition

This SAMA analysis case was used to evaluate the change in plant risk from installing a passive hydrogen control system or from providing post-accident containment inerting capability. A bounding analysis was performed by eliminating failure of hydrogen igniters in the PSA model [gate E61-001 was set to zero], which resulted in an internal and external benefit (with uncertainty) of approximately $427,365. This analysis case was used to model the benefit of Phase II SAMAs 44 and 45.

Case 33: Controlled Containment Venting

This analysis case was used to evaluate the change in plant risk from enabling manual operation of all containment vent valves via local controls or from providing passive overpressure relief. A bounding analysis was performed by eliminating failure of air-operated valves to open in the PSA model [gates M41-002, M41-002-SBO, and M41-002X were set to zero], which resulted in an internal and external benefit (with uncertainty) of approximately $93,240. This analysis case was used to model the benefit of Phase II SAMAs 46 and 47.

Case 34: ISLOCA

This analysis case was used to evaluate the change in plant risk from reducing the probability of an ISLOCA by increasing the frequency of valve leak testing or improving ISLOCA identification or coping. A bounding analysis was performed by setting the ISLOCA initiators to zero in the PSA model [initiators %VPCIC, %VLPCS, and %VSDC were set to zero], which resulted in an internal and external benefit (with uncertainty) of approximately $231. This analysis case was used to model the benefit of Phase II SAMAs 48, 50, and 51.

Case 35: MSIV Design

This analysis case was used to evaluate the change in plant risk from improving MSIV design to decrease the likelihood of containment bypass scenarios. A bounding analysis was performed by eliminating failure of the MSIVs to close or remain closed in the PSA model [gates DL-MSIV, IS-MSIV, and IS-MSIV-INIT were removed from the model], which resulted in an internal and external benefit (with uncertainty) of approximately $30,093. This analysis case was used to model the benefit of Phase II SAMA 49.

Case 36: Standby Liquid Control (SLC) System

This analysis case was used to evaluate the change in plant risk from increasing boron concentration in the SLC system. A bounding analysis was performed by eliminating the contribution due to failure to initiate SLC and failures of alternate boron injection in the PSA model [gate SLC was removed from the model and basic event ABI was set to zero], which resulted in an internal and external benefit (with uncertainty) of approximately $31,849. This analysis case was used to model the benefit of Phase II SAMA 52.

Case 37: SRV Reseat

This analysis of case was used to evaluate the change in plant risk from installing more reliable SRVs. A bounding analysis was performed by eliminating the initiator for the SRVs inadvertently being open and the basic events for stuck open SRVs in the PSA model [initiator %T3C, basic events P1 and P2 were set to zero], which resulted in an internal and external benefit (with uncertainty) of approximately $87,324. This analysis case was used to model the benefit of Phase II SAMA 53.

Case 38: Add Fire Suppression

This analysis case was used to evaluate the change in plant risk from adding automatic fire suppression systems to the dominant fire zones. The dominant fire zones reported in the IPEEE are the control room and control building switchgear rooms. The control room has Halon suppression in the control room floor sections. Many of the switchgear rooms have automatic CO_2 suppression systems. The Div I switchgear room in the control building that is a large contributor in the IPEEE is zone OC202 in compartment CC202, which has a partial automatic sprinkler system.

For the main control, an automatic suppression system would not provide a significant safety benefit. The sensing devices used for fires include both fuse elements that melt given high temperature and smoke detectors. These types of actuation devices would only actuate after the fire has progressed to a point that would cause evacuation of the control room. Even if the auto suppression system actuated prior to evacuation, the consequences of actuation would require evacuation. Additional Halon or CO_2 systems would asphyxiate any personnel remaining in the main control room and water would damage the control equipment. Given that the main control room fire risk is dominated by failure to shut down the reactor from outside the control room, extremely limited benefit is judged to exist for auto suppression systems in the main control room.

Thus, this SAMA evaluates improving the reliability and effectiveness of the suppression systems in the switchgear rooms. A bounding analysis was performed as described below, which resulted in an internal and external benefit (with uncertainty) of approximately $102,345. This analysis case was used to model the benefit of Phase II SAMA 54.

This analysis case (Adding automatic fire suppression systems to the critical switchgear rooms) is an external events SAMA, which would not mitigate internal event risk. Many of the switchgear rooms have automatic CO_2 suppression systems. The Div I switchgear room in the control building that is a large contributor in the IPEEE is zone OC202, which has a partial automatic sprinkler system. This SAMA would improve the reliability and effectiveness of those systems. A bounding analysis was performed by assuming the SAMA would eliminate the contribution to fire CDF from fires in critical switchgear room OC202. Since the total fire CDF is 2.74E-05/yr [Table E.1-10] and the critical switchgear room fire CDF is 9.37E-07/yr, fires in the critical switchgear rooms contribute 3.42% of the total fire CDF.

The internal events model cannot be used to assess the benefit from this external event SAMA. However, the consequences resulting from fire-induced core damage and internal event-induced core damage would be comparable. Since we have already estimated the maximum benefit from removing all internal event risk, the maximum benefit of removing all fire risk was estimated by reducing the maximum internal event benefit by the ratio of the total fire CDF to the internal event CDF. Since this SAMA analysis case would eliminate 3.42% of the total fire risk, the benefit for this SAMA analysis case was estimated to be 3.42% of the total fire benefit as shown below.

Given,

Maximum internal benefit is $74,673 [Table 4.21-1]
Total fire CDF = 2.74E-05/rx-yr [Table E.1-10]
Internal events CDF = 2.05E-06/rx-yr

Maximum fire benefit = Maximum internal benefit x Total fire CDF/Internal events CDF

Maximum fire benefit = $74,673 x (2.74E-05/2.05E-06)= $997,559
SAMA case 38 benefit = 3.42% x (Maximum fire benefit) = 0.0342 x $997,559
SAMA case 38 benefit = $34,115

Applying the uncertainty factor of 3,

SAMA case 38 benefit with uncertainty = $34,115 x 3 = $102,345

Case 39: Reduce Risk from Fires that Require Control Room Evacuation

The alternate shutdown system (ASDS) panel is designed to use division 1 safety and support systems to safely shutdown the plant. This analysis case was used to evaluate the change in plant risk from upgrading the ASDS panel to include additional system controls for the other division. A bounding analysis was performed as described below, which resulted in an internal and external benefit (with uncertainty) of approximately $420,521. This analysis case was used to model the benefit of Phase II SAMA 55.

This SAMA analysis case is an external events SAMA, which would not mitigate internal event risk. A bounding analysis was performed by assuming the SAMA would eliminate the contribution to fire CDF from fires in the control room. Since the total fire CDF is 2.74E-05/yr and the control room fire CDF is 3.85E 06/yr, fires in the control room contribute 14.05% of the total fire CDF.

The internal events model cannot be used to assess the benefit from this external event SAMA. However, the consequences resulting from fire-induced core damage and internal event-induced core damage would be comparable. Since we have already estimated the maximum benefit from removing all internal event risk, the maximum benefit of removing all fire risk can be estimated by reducing the maximum internal event benefit by the ratio of the total fire CDF to the internal event CDF. Since this SAMA analysis case would eliminate 14.05% of the total fire risk, the benefit for this SAMA analysis case was estimated to be 14.05% of the total fire benefit as shown below.

Given,

Maximum internal benefit is $74,673 [Table 4.21-1]
Total fire CDF = 2.74E-05/rx-yr [Table E.1-10]
Internal events CDF = 2.05E-06/rx-yr

Maximum fire benefit = Maximum internal benefit x Total fire CDF/Internal events CDF

Maximum fire benefit = $74,673 x (2.74E-05/2.05E-06) = $997,599
SAMA case 39 benefit = 14.05% x (Maximum fire benefit) = 0.1405 x $997,599
SAMA case 39 benefit = $140,174

Applying the uncertainty factor of 3,

SAMA case 39 benefit with uncertainty = $140174 x 3 = $420,521

Case 40: Large Break LOCA

This analysis case was used to evaluate the change in plant risk from installing a digital large break LOCA protection system. A bounding analysis was performed by setting the large LOCA initiator to zero in the PSA model [initiator %A was set to zero], which resulted in an internal and external benefit (with uncertainty) of approximately $948,372. This analysis case was used to model the benefit of Phase II SAMA 56.

Case 41: Trip/Shutdown Risk

This analysis case was used to evaluate the change in plant risk from implementing Generation Risk Assessment (trip and shutdown risk modeling) in plant activities. It is assumed that this would reduce the frequency of plant trips and shutdowns. A bounding analysis was performed by reducing all initiating event frequencies except pipe breaks, floods, and LOSP by 10% [the following initiating events were reduced: %T2, %T2M, %T3A, %T3B, %T3C, %TAC1, %TAC2, %TBCW, %TCCW, %TCRD, %TDC1, %TDC2, %TIA, %TPSW, %TST11, and %TST21], which resulted in an internal and external benefit (with uncertainty) of approximately $187,117. This analysis case was used to model the benefit of Phase II SAMA 57.

Case 42: Increase Availability of SSW Pump House Ventilation System

This analysis case was used to evaluate the change in plant risk from increasing the training emphasis and providing additional control room indication on the operational status of the SSW pump house ventilation system. This will allow operators to manually open the pump house dampers, which can provide adequate ventilation such that pump failures would not occur. A bounding analysis was performed by eliminating failure of SSW Pump House Ventilation in the PSA model [the following gates were removed from the model: HVC-1000X, HVC-1000XP, HVC-1000XZ, HVC-1000-HPCS, HVC-1000X-HPCS, HVC-1000X-ONSP, HVC-1000X-SBO, and HVC-2000X], which resulted in an internal and external benefit (with uncertainty) of approximately $45,212. This analysis case was used to model the benefit of Phase II SAMA 58.

Case 43: Increase Recovery Time of ECCS upon Loss of SSW

This analysis case was used to evaluate the change in plant risk from upgrading procedures and increasing operator training for alternating operation of the low pressure ECCS pumps (LPCI and LPCS) for loss of SSW scenarios. A bounding analysis was performed by eliminating failure of the SSW to the LPCS room cooler in the PSA model [gate P41-LPCS was removed from the model], which resulted in an internal and external benefit (with uncertainty) of approximately $121,357. This analysis case was used to model the benefit of Phase II SAMA 59.

Case 44: Additional Containment Heat Removal

This analysis of case was used to evaluate the change in plant risk from installing an additional method of removing heat from the containment. A bounding analysis was performed by eliminating failure of suppression pool cooling and containment spray systems in the PSA model [the following gates were removed from the model: RH--SY-SPCSYS-F-, E12-199, E12-199X, E12-199XX, E12-199X-SBO, E12-199Y, E12-199Y-SBO, E12-199-SBO, E12-199-CSS, E12-600, E12-600X, E12-600XX, E12-600X-SBO, E12-600Y, E12-600Y-SBO, and E12-600-SBO], which resulted in an internal and external benefit (with uncertainty) of approximately $894,362. This analysis case was used to model the benefit of Phase II SAMA 60.

Case 45: Improve RHR Heat Exchanger Availability

This SAMA analysis case was used to evaluate the change in plant risk from adding a bypass around the RHR HX inlet and outlet valves. A bounding analysis was performed by eliminating failure of RHR HX Cooler inlet and outlet valves in the PSA model [the following basic events were set to zero: P41-CC-MVF014A-L, P41-CC-MVF014B-L, P41-CC-MVF068A-L, P41-CC-MVF068B-L, P41-CF-MVF14AB-L, and P41-CF-MVF68AB-L], which resulted in an internal and external benefit (with uncertainty) of approximately $124,019. This analysis case was used to model the benefit of Phase II SAMA 62.

Case 46: Improve RCIC Lube Oil Cooling

This analysis case was used to evaluate the change in plant risk from adding a redundant RCIC lube oil cooling path. A bounding analysis was performed by eliminating the failure to cool RCIC lube oil in the PSA model [gate E51-043-G was set to zero], which resulted in an internal and external benefit (with uncertainty) of approximately $92,683. This analysis case was used to model the benefit of Phase II SAMA 63.

E.2.4 <u>Sensitivity Analyses</u>

Two sensitivity analyses were conducted to gauge the impact of assumptions upon the analysis. The benefits estimated for each of these sensitivities are presented in Table E.2-3.

A description of each sensitivity case follows.

Sensitivity Case 1: Years Remaining Until End of Plant Life

The purpose of this sensitivity case was to investigate the sensitivity of assuming a 33-year period for remaining plant life (i.e., thirteen years on the original plant license plus the 20-year license renewal period), rather than the 20-year license renewal period used in the base case. Changing this assumption does not cause additional SAMAs to be cost-beneficial.

Sensitivity Case 2: Conservative Discount Rate

The purpose of this sensitivity case was to investigate the sensitivity of each analysis case to the discount rate. The discount rate of 7.0% used in the base case analyses is conservative relative to corporate practices. Nonetheless, a lower discount rate of 3.0% was assumed in this case to investigate the impact on each analysis case. Changing this assumption does not cause additional SAMAs to be cost-beneficial.

E.2.5 References

E.2-1 Nuclear Energy Institute (NEI), NEI 05-01, *Severe Accident Mitigation Alternatives (SAMA) Analysis Guidance Document*, November 2005, Revision A.

E.2-2 U.S. Nuclear Regulatory Commission (USNRC), NUREG-1437, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants Regarding James A. FitzPatrick Nuclear Power Plant (NUREG-1437, Supplement 31) Final Report*, January 2008.

E.2-3 USNRC, NUREG-1437, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants Regarding Vermont Yankee Nuclear Power Station (NUREG-1437, Supplement 30) Final Report*, August 2007.

E.2-4 USNRC, NUREG-1437, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants Regarding Pilgrim Nuclear Power Station (NUREG-1437, Supplement 29) Final Report*, July 2007.

E.2-5 USNRC, NUREG-1437, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants Regarding Oyster Creek Nuclear Generating Station (NUREG-1437, Supplement 28) Final Report*, January 2007.

E.2-6 USNRC, NUREG-1437, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants Regarding Monticello Nuclear Generating Plant (NUREG-1437, Supplement 26) Final Report*, August 2006.

E.2-7 USNRC, NUREG-1437, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants Regarding Brunswick Steam Electric Plant, Units 1 and 2 (NUREG-1437, Supplement 25) Final Report*, April 2006.

E.2-8 USNRC, NUREG-1742 *Perspectives Gained From the Individual Plant Examination of External Events (IPEEE) Program*, Volumes 1 & 2, Final Report April 2002.

E.2-9 USNRC, NUREG-1437, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants Regarding Cooper Nuclear Station (NUREG-1437, Supplement 41) Final Report*, July 2010.

E.2-10 USNRC, NUREG-1437, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants Regarding Susquehanna Steam Electric Station, Units 1 and 2 (NUREG-1437, Supplement 35) Final Report*, March 2009.

E.2-11 USNRC, NUREG-1437, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants Regarding Duane Arnold Energy Center (NUREG-1437, Supplement 42) Final Report*, October 2010.

E.2-12 USNRC, NUREG-1437, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants Regarding Hope Creek Generating Station and Salem Nuclear Generating Station, Units 1 and 2 (NUREG-1437, Supplement 45) Final Report*, March 2011.

E.2-13 GGNS94-0054 IPEEE "Internal Plant Examination of External Events Summary Report," Revision 1.

E.2-14 GGNS95-00041 IPEEE "Internal Plant Examination of External Events Fire," Revision 0.

E.2-15 GGNS94-0053 IPEEE "Internal Plant Examination of External Events Seismic Margins," Revision 0.

E.2-16 GGNS94-0051IPEEE "Internal Plant Examination of External Events Fire Modeling," Revision 1.

E.2-17 GGNS93-0048 IPEEE "Internal Plant Examination of External Events High Wind and Tornado Assessment," Revision 0.

E.2-18 Grand Gulf Nuclear Station Individual Plant Examination Summary Report (IPE), December 1992.

E.2-19 Energy Northwest, License Renewal Application, Appendix E, "Applicant's Environmental Report, Operating License Renewal Stage, Columbia Generating Station, Energy Northwest," January 2010.

E.2-20 USNRC, NUREG/BR-0184, *Regulatory Analysis Technical Evaluation Handbook*, January 1997.

E.2-21 CALC-OC-N1000-10003, "Cost-Benefit Analysis of Severe Accident Mitigation Alternatives," Revision 0.

Table E.2-1
Phase I SAMAs Related to IPE and IPEEE Insights

Phase I SAMA ID Number	SAMA Title	Result of Potential Enhancement	Screening Results	SAMA Disposition	Credited in PSA Model
226	The Loss of Offsite Power Off-Normal Event Procedure will be revised to allow for the Level 2 signal to be bypassed in the event that the Division 3 diesel generator must be cross-tied to Divisions 1 or 2.	Increased availability of on-site AC power leading to increased availability of ECCS injection.	#3 – Already installed	The Loss of AC Power Off-Normal Event Procedure has been revised to allow for the level 2 signal to be bypassed in the event that the Division 3 diesel generator must be cross-tied to divisions 1 or 2.	Yes

Table E.2-1 (Continued)
Phase I SAMAs Related to IPE and IPEEE Insights

Phase I SAMA ID Number	SAMA Title	Result of Potential Enhancement	Screening Results	SAMA Disposition	Credited in PSA Model
227	Improve secondary containment isolation to allow the capability of bypassing the isolation signals and re-opening the valves.	Improved availability of PSW and Instrument Air such that the main condenser, condensate, and feedwater systems would not be lost. CRD would also not be degraded due to a loss of the preferred cooling source of the component cooling water (CCW) heat exchangers.	#3 – Already installed	The PSW isolation valves in the Auxiliary Building penetrations (P44-F1I6, P44-FI17, P44-FII8, P44-FII9, P44-FI20, P44-FI2I, P44-FI22 and P44-FI23) can be reopened by manual override after a LOCA to reestablish PSW cooling to the CCW heat exchangers, computer room coolers, plant chillers, steam tunnel coolers, and drywell coolers. This should be done only if offsite power is available and after it has been determined that the release of radioactive fission products will not result. 05-S-01-EP-1 contains guidance to restore instrument air to containment loads by defeating containment isolation interlocks and opening the valves.	Yes

Table E.2-1 (Continued)
Phase I SAMAs Related to IPE and IPEEE Insights

Phase I SAMA ID Number	SAMA Title	Result of Potential Enhancement	Screening Results	SAMA Disposition	Credited in PSA Model
228	Implement procedural changes to allow for bypass of the RCIC turbine trip due to main steam tunnel (MST) high temperature when PSW is unavailable and no steam line break has occurred.	Increased RCIC availability when main steam tunnel high temperature exists.	#1 – N / A	Provided there is no leak in the main steam tunnel, failure of main steam cooling will not result in a MST temperature of 185°F or greater. Therefore, it will not result in an initiation of the MST high temperature isolation logic.	No
229	Increase the training emphasis and provide additional control room indication on the operational status of the SSW pump house ventilation system. This will allow operators to manually open the pump house dampers, which can provide adequate ventilation such that pump failures would not occur.	Increased availability of the SSW pump house ventilation system.	Retain (Phase II SAMA 58)	In accordance with GDC 13, damper status is indicated in the main control room. In addition, there is a high temperature alarm in the main control room. Alarm 04-1-02-1H13-P870 provides an alarm, but the actions could be expanded to accomplish a more robust mitigation of this condition.	No
230	Increase operator training for alternate operation of the low pressure ECCS pumps (LPCI and LPCS) for loss of SSW scenarios.	Increased time available for recovery actions for low pressure ECCS when a loss of SSW occurs.	Retain (Phase II SAMA 59)	No specific operator training is in place to address this condition.	No

Table E.2-1 (Continued)
Phase I SAMAs Related to IPE and IPEEE Insights

Phase I SAMA ID Number	SAMA Title	Result of Potential Enhancement	Screening Results	SAMA Disposition	Credited in PSA Model
231	Revise the containment flooding portion of the Emergency Procedures to remove or modify the step requiring MSIV venting.	Limit one of the major contributors to the source term released.	#3 – Already installed	GGNS contributed this IPE insight to the BWR Owners Group Severe Accident Subcommittee. GGNS has already implemented the current SAGs on RPV venting.	Yes
232	Install a backup power supply to the hydrogen igniters.	Hydrogen igniter operability during station blackout.	#3 – Already Installed	GGNS has two hydrogen recombiners, each powered from a different division. They are backed up by hydrogen igniters and a drywell purge system. Also, GGNS has a portable generator used to supply temporary power to one division of hydrogen igniters.	No
233	Install an additional method of removing heat from the containment.	Increased decay heat removal capability	Retain (Phase II SAMA 60)	GGNS utilizes the containment spray and RHR suppression pool cooling for post-accident containment heat removal. Containment venting is also available to ensure pressure stays below design limits should the other systems fail to reduce containment pressure.	No

**Table E.2-1 (Continued)
Phase I SAMAs Related to IPE and IPEEE Insights**

Phase I SAMA ID Number	SAMA Title	Result of Potential Enhancement	Screening Results	SAMA Disposition	Credited in PSA Model
234	Install a backup water supply and pumping capability that is independent of normal and emergency AC power.	Alternate water supply for containment spray/vessel injection	Retain (Phase II SAMA 61)	GGNS has a high pressure core spray system, which is powered from an independent (Division 3) power supply; however, a backup supply will be investigated per the IPE recommendations.	No
235	Extend the battery depletion time for the relief valves.	Enhanced reactor pressure vessel depressurization system reliability	#2 – Similar item is addressed under other proposed SAMAs	ADS and Non-ADS relief valves are all dependent on DC power and instrument air. Extended DC power to the relief valves will allow longer operation during a loss of DC battery chargers. Similar to Phase II SAMAs 1, 3, and 27.	No
236	Implement the latest revision of the BWR Owners Group emergency procedure guidelines (EPGs).	Improved likelihood of success of operator actions taken in response to abnormal conditions.	#3 – Already Installed	GGNS currently utilizes Revision 2 of the BWROG EPGs.	Yes
237	Increase maintenance on drainage structures. Maintenance should include cleaning of culverts, concrete repair, and removal of vegetation/debris which could obstruct flow.	Prevent deterioration of site conditions.	#3 – Already installed	GGNS has increased the maintenance on drainage structures.	No

Table E.2-1 (Continued)
Phase I SAMAs Related to IPE and IPEEE Insights

Phase I SAMA ID Number	SAMA Title	Result of Potential Enhancement	Screening Results	SAMA Disposition	Credited in PSA Model
238	Plant procedures currently require plant staff to insure that plant doors are closed during severe weather and in the event of plant flooding (Implicitly including former Unit 2 doors). Revise procedures to explicitly include at-grade former Unit 2 doors.	Reduce leakage from flooding through an open door.	#3 – Already installed	GGNS has revised the plant flood mitigation procedure.	No
239	Revise procedures to periodically inspect roof drains and overflows to ensure they are not blocked.	Reduce the consequences of a flood.	#3 – Already installed	GGNS has created an inspection procedure for roof drains, roof drainage system, and roof overflows.	No

Table E.2-1 (Continued)
Phase I SAMAs Related to IPE and IPEEE Insights

Phase I SAMA ID Number	SAMA Title	Result of Potential Enhancement	Screening Results	SAMA Disposition	Credited in PSA Model
240	Remove the wooden foot bridge crossing the northwest ditch near its upstream end.	Improve site drainage/ external flood protection.	#1 – N/A	The IPEEE showed the risk from external flooding at GGNS is minor. Thus this potential modification is assumed not to be cost beneficial, which follows the same assumption in the NRC safety evaluation report. In May 2011, NRC Inspectors verified that the plant grade is 132.5 feet above mean sea level and that the maximum expected flood height from the Mississippi River is about 103 feet above mean sea level. Therefore, floodwaters from the Mississippi River are not expected to impact the plant.	No

Table E.2-1 (Continued)
Phase I SAMAs Related to IPE and IPEEE Insights

Phase I SAMA ID Number	SAMA Title	Result of Potential Enhancement	Screening Results	SAMA Disposition	Credited in PSA Model
241	Remove the 15" corrugated metal pipe located in the small auxiliary ditch parallel to the northwest ditch (at the same approximate location as the duct bank crossing the northwest ditch). Re-grade the area to provide a gradual transition between the yard upstream and the auxiliary ditch.	Improve site drainage/ external flood protection.	#1 – N/A	The IPEEE showed the risk from external flooding at GGNS is minor. Thus this potential modification is assumed not to be cost beneficial, which follows the same assumption in the NRC safety evaluation report. In May 2011, NRC Inspectors verified that the plant grade is 132.5 feet above mean sea level and that the maximum expected flood height from the Mississippi River is about 103 feet above mean sea level. Therefore, floodwaters from the Mississippi River are not expected to impact the plant.	No

Table E.2-1 (Continued)
Phase I SAMAs Related to IPE and IPEEE Insights

Phase I SAMA ID Number	SAMA Title	Result of Potential Enhancement	Screening Results	SAMA Disposition	Credited in PSA Model
242	Re-hang the security fence gates west of the control building to insure that approximately 5" of gap exists between the gate and the road.	Improve site drainage/ external flood protection.	#1 – N/A	The IPEEE showed the risk from external flooding at GGNS is minor. Thus this potential modification is assumed not to be cost beneficial, which follows the same assumption in the NRC safety evaluation report. In May 2011, NRC Inspectors verified that the plant grade is 132.5 feet above mean sea level and that the maximum expected flood height from the Mississippi River is about 103 feet above mean sea level. Therefore, floodwaters from the Mississippi River are not expected to impact the plant.	No

Table E.2-1 (Continued)
Phase I SAMAs Related to IPE and IPEEE Insights

Phase I SAMA ID Number	SAMA Title	Result of Potential Enhancement	Screening Results	SAMA Disposition	Credited in PSA Model
243	Grade down and remove the access road, the raised berm parallel to the access road, and curbs adjacent to the access road as necessary where they cross Culvert No.1, such that elevations above the culvert do not exceed 132.7 ft. MSL.	Improve site drainage/ external flood protection.	#1 – N/A	The IPEEE showed the risk from external flooding at GGNS is minor. Thus this potential modification is assumed not to be cost beneficial, which follows the same assumption in the NRC safety evaluation report. In May 2011, NRC Inspectors verified that the plant grade is 132.5 feet above mean sea level and that the maximum expected flood height from the Mississippi River is about 103 feet above mean sea level. Therefore, floodwaters from the Mississippi River are not expected to impact the plant.	No

Table E.2-1 (Continued)
Phase I SAMAs Related to IPE and IPEEE Insights

Phase I SAMA ID Number	SAMA Title	Result of Potential Enhancement	Screening Results	SAMA Disposition	Credited in PSA Model
244	Replace the C8x11.5 channel forming the flood barrier across the SSW A equipment hatch opening with another member having a minimum depth of approximately 13".	Improve site drainage/ external flood protection.	#1 – N/A	The IPEEE showed the risk from external flooding at GGNS is minor. Thus this potential modification is assumed not to be cost beneficial, which follows the same assumption in the NRC safety evaluation report. In May 2011, NRC Inspectors verified that the plant grade is 132.5 feet above mean sea level and that the maximum expected flood height from the Mississippi River is about 103 feet above mean sea level. Therefore, floodwaters from the Mississippi River are not expected to impact the plant.	No
245	Modify the piping systems to account for the grouted condition for the penetration of the standby service water (SSW) piping in the control building.	Reduce vulnerability to a seismic event.	#3 – Already installed	The grout was removed and the pipe support at the penetration was modified to coincide with the design basis piping analysis assumption.	No

Table E.2-2
Summary of Phase II SAMA Candidates Considered in Cost-Benefit Evaluation

Analysis Case (bold) SAMA Number and Title	Assumptions	CDF Reduction	PDR Reduction	OECR Reduction	Internal and External Benefit	Internal and External Benefit with Uncertainty	GGNS Cost Estimate	Conclusion
1. DC Power	Eliminates all SBO cutsets	13.6%	16.5%	13.6%	$115,656	$346,968		
1 – Provide additional DC battery capacity	CNS estimate.						$500,000	Not cost effective
2 – Replace lead-acid batteries with fuel cells	CNS estimate.						$1,000,000	Not cost effective
11 – Portable generator for direct current (DC) power: This SAMA involves the use of a portable generator to supply DC power to the battery chargers during a station blackout.	CNS had different cost estimates for the portable generator to supply the charger and the portable generator to supply a panel because they had an existing generator big enough to supply the charger, but not big enough to supply a panel. (cont. below)						$714,000	Not cost effective

Table E.2-2 (Continued)
Summary of Phase II SAMA Candidates Considered in Cost-Benefit Evaluation

Analysis Case (bold) SAMA Number and Title	Assumptions	CDF Reduction	PDR Reduction	OECR Reduction	Internal and External Benefit	Internal and External Benefit with Uncertainty	GGNS Cost Estimate	Conclusion
(cont.)	Since GGNS does not have an existing generator that can be used for either purpose, the CNS estimate for a new generator is appropriate. Thus, GGNS SAMA 11 cost estimate should be the same as GGNS SAMA 12 cost estimate.							
12 – Portable generator for direct current (DC) power: This SAMA involves the use of a portable generator to supply DC power to the individual panels during a station blackout.	CNS estimate.						$714,000	Not cost effective

Table E.2-2 (Continued)
Summary of Phase II SAMA Candidates Considered in Cost-Benefit Evaluation

Analysis Case (bold) SAMA Number and Title	Assumptions	CDF Reduction	PDR Reduction	OECR Reduction	Internal and External Benefit	Internal and External Benefit with Uncertainty	GGNS Cost Estimate	Conclusion
15 – Use DC generators to provide power to operate the switchyard power control breakers while a 480-V AC generator could supply the air compressors for breaker support.	GGNS SAMA 11 and SAMA 12 estimate that one generator would cost ~$714,000. This SAMA recommends addition of at least two generators. Thus, GGNS SAMA 15 cost estimate should be at least double that for SAMA 11 or 12.						$1,428,000	Not cost effective
2. Improve Charger Reliability	Failure of chargers contribution to zero.	1.4%	2.2%	2.3%	$13,598	$40,793		
3 – Add battery charger to existing DC system	CNS estimate.						$90,000	Not cost effective
13 – Proceduralize battery charger high-voltage shutdown circuit inhibit	CNS estimate.						$50,000	Not cost effective

Table E.2-2 (Continued)
Summary of Phase II SAMA Candidates Considered in Cost-Benefit Evaluation

Analysis Case (bold) SAMA Number and Title	Assumptions	CDF Reduction	PDR Reduction	OECR Reduction	Internal and External Benefit	Internal and External Benefit with Uncertainty	GGNS Cost Estimate	Conclusion
3. Add DC System Cross-ties	Eliminate failure of DC power gates.	7.6%	11.6%	11.8%	$73,056	$219,169		
4 – Provide DC bus cross-ties	CNS estimate.						$300,000	Not cost effective
4. Increase Availability of On-Site AC Power	Eliminated failure of DG11, DG12, and DG13 to their AC Busses	17.5%	21.2%	18.5%	$149,396	$448,189		
5 – Provide an additional diesel generator	CNS estimate.						$20,000,000	Not cost effective
8 – Install a gas turbine generator with tornado protection	CNS estimate.						$2,000,000	Not cost effective
5. Improve AC Power	Eliminated the loss of the 4.16-kV buses	20.4%	25.6%	23.2%	$177,524	$532,571		
6 – Improve 4.16-kV bus cross-tie ability	CNS estimate.						$656,000	Not cost effective

Table E.2-2 (Continued)
Summary of Phase II SAMA Candidates Considered in Cost-Benefit Evaluation

Analysis Case (bold) SAMA Number and Title	Assumptions	CDF Reduction	PDR Reduction	OECR Reduction	Internal and External Benefit	Internal and External Benefit with Uncertainty	GGNS Cost Estimate	Conclusion
17 – Provide alternate feeds to essential loads directly from an alternate emergency bus	Modification of the AC system to allow alignment of alternate feeds to the 4kV loads is greater in scope than an AC crosstie modification. SAMA 6, Improve 4.16-kV bus cross-tie ability, is estimated to cost $656,000. Thus, this is a lower bound estimate for SAMA 17.						$656,000	Not cost effective
6. Reduce Loss of Off-Site Power During Severe Weather	Eliminate the weather centered loss of off-site power initiating event.	3.1%	3.7%	3.1%	$26,087	$78,261		
7 – Install an additional, buried off-site power source.	CNS estimate.						$2,485,000	Not cost effective

Table E.2-2 (Continued)
Summary of Phase II SAMA Candidates Considered in Cost-Benefit Evaluation

Analysis Case (bold) SAMA Number and Title	Assumptions	CDF Reduction	PDR Reduction	OECR Reduction	Internal and External Benefit	Internal and External Benefit with Uncertainty	GGNS Cost Estimate	Conclusion
7. Provide Backup EDG Cooling	Eliminated failure of SW cooling to the EDGs	1.9%	2.5%	1.9%	$16,515	$49,545		
9 – Use fire water system as backup source for diesel cooling	Hardware modification range estimate.						$100,000	Not cost effective
10 – Add new backup source of diesel cooling	CNS estimate.						$2,000,000	Not cost effective
8. Increase EDG Reliability	Eliminated failure of EDGs to run	3.3%	4.6%	4.5%	$30,348	$91,044		
14 – Provide a portable EDG fuel oil transfer pump	CNS estimate.						$100,000	Not cost effective

Table E.2-2 (Continued)
Summary of Phase II SAMA Candidates Considered in Cost-Benefit Evaluation

Analysis Case (bold) SAMA Number and Title	Assumptions	CDF Reduction	PDR Reduction	OECR Reduction	Internal and External Benefit	Internal and External Benefit with Uncertainty	GGNS Cost Estimate	Conclusion
9. Improve DG Reliability	Eliminated the common cause failure (CCF) contribution of failure to start EDGs	0.3%	0.3%	0.2%	$2,181	$6,542		
16 – Provide a diverse swing diesel generator air start compressor	Hardware modification range estimate.						$100,000	Not cost effective
10. Reduce Plant-Centered Loss of Off-Site Power	Removed the contribution of plant- and switchyard-centered events	9.1%	10.7%	8.9%	$76,556	$229,668		
18 – Protect transformers from failure	CNS estimate.						$780,000	Not cost effective

Table E.2-2 (Continued)
Summary of Phase II SAMA Candidates Considered in Cost-Benefit Evaluation

Analysis Case (bold) SAMA Number and Title	Assumptions	CDF Reduction	PDR Reduction	OECR Reduction	Internal and External Benefit	Internal and External Benefit with Uncertainty	GGNS Cost Estimate	Conclusion
11. Redundant Power to Torus Hard Pipe Vent (THPV) Valves	Eliminated failure of power to containment vents	1.1%	1.8%	1.8%	$10,766	$32,297		
19 – Provide redundant power to direct torus hard pipe vent valves to improve the reliability of the direct torus vent valves and enhance the containment heat removal capability.	CNS estimate.						$714,000	Not cost effective

Table E.2-2 (Continued)
Summary of Phase II SAMA Candidates Considered in Cost-Benefit Evaluation

Analysis Case (bold) SAMA Number and Title	Assumptions	CDF Reduction	PDR Reduction	OECR Reduction	Internal and External Benefit	Internal and External Benefit with Uncertainty	GGNS Cost Estimate	Conclusion
12. High Pressure Injection System	Eliminated failure of the HPCS	77.8%	61.8%	60.2%	$594,912	$1,784,736		
20 – Install an independent active or passive high pressure injection system	Recent BWR cost estimates for this SAMA are ~$2M at Duane Arnold, ~$4M at Susquehanna, ~$5M at Vermont Yankee, and ~$29M at Columbia. SAMA 24, Add a diverse low pressure injection system, is estimated to cost $8,800,000. Since a high pressure system would cost at least as much as a low pressure system, this estimate is appropriate.						$8,800,000	Not cost effective

Table E.2-2 (Continued)
Summary of Phase II SAMA Candidates Considered in Cost-Benefit Evaluation

Analysis Case (bold) SAMA Number and Title	Assumptions	CDF Reduction	PDR Reduction	OECR Reduction	Internal and External Benefit	Internal and External Benefit with Uncertainty	GGNS Cost Estimate	Conclusion
61 – Install a backup water supply and pumping capability that is independent of normal and emergency AC power	Plant-specific cost estimate.						$6,409,949	Not cost effective
13. Extend RCIC Operation	Eliminated failure of trip due to pressure	1.0%	1.6%	1.7%	$10,031	$30,093		
21 – Raise HPCI/ RCIC backpressure trip set points [HPCI backpressure trip setpoint has already been raised. This SAMA will evaluate raising the RCIC backpressure trip set point].	CNS estimate.						$200,000	Not cost effective

**Table E.2-2 (Continued)
Summary of Phase II SAMA Candidates Considered in Cost-Benefit Evaluation**

Analysis Case (bold) SAMA Number and Title	Assumptions	CDF Reduction	PDR Reduction	OECR Reduction	Internal and External Benefit	Internal and External Benefit with Uncertainty	GGNS Cost Estimate	Conclusion
14. Improve ADS System	Eliminated failure of ADS valves	45.9%	16.3%	16.0%	$299,106	$897,317		
22 – Modify automatic depressurization system components to improve reliability [This SAMA will add larger accumulators thus increasing reliability during SBOs].	Plant-specific cost estimate.						$1,176,850	Not cost effective
15. Improve ADS Signals	Eliminated failure of the SRV failing to open	20.8%	5.3%	4.8%	$129,383	$388,150		
23 – Add signals to open safety relief valves automatically in an MSIV closure transient.	CNS estimate.						$1,500,000	Not cost effective

Table E.2-2 (Continued)
Summary of Phase II SAMA Candidates Considered in Cost-Benefit Evaluation

Analysis Case (bold) SAMA Number and Title	Assumptions	CDF Reduction	PDR Reduction	OECR Reduction	Internal and External Benefit	Internal and External Benefit with Uncertainty	GGNS Cost Estimate	Conclusion
16. Low Pressure Injection System	Eliminated failure of the LPCI and LPCS	22.9%	39.5%	38.3%	$229,965	$689,896		
24 – Add a diverse low pressure injection system.	CNS estimate.						$8,800,000	Not cost effective
17. ECCS Low Pressure Interlock	Eliminated ECCS permissives and interlock failure	1.0%	1.6%	1.7%	$10,031	$30,093		
25 – Install a bypass switch to allow operators to bypass the low reactor pressure interlock circuitry that inhibits opening the LPCI or core spray injection valves following sensor or logic failures that prevent all low pressure injection valves from opening.	CNS estimate.						$1,000,000	Not cost effective

Table E.2-2 (Continued)
Summary of Phase II SAMA Candidates Considered in Cost-Benefit Evaluation

Analysis Case (bold) SAMA Number and Title	Assumptions	CDF Reduction	PDR Reduction	OECR Reduction	Internal and External Benefit	Internal and External Benefit with Uncertainty	GGNS Cost Estimate	Conclusion
18. RHR Heat Exchangers	Eliminated failure of SSW to provide cooling to the RHR heat exchangers	18.5%	37.4%	39.9%	$205,223	$615,669		
26 – Implement modifications to allow manual alignment of the fire water system to RHR heat exchangers.	Pilgrim estimate.						$1,950,000	Not cost effective
19. Emergency Service Water System Reliability	Eliminated failure of service water pumps	3.6%	6.7%	7.0%	$37,903	$113,708		
27 – Add a service water pump to increase availability of cooling water	CNS estimate.						$5,900,000	Not cost effective
20. Main Feedwater System Reliability	Eliminated failure to inject from feedwater	19.3%	20.5%	20.6%	$162,050	$486,149		
28 – Add a motor-driven feed water pump	CNS estimate.						$1,650,000	Not cost effective

Table E.2-2 (Continued)
Summary of Phase II SAMA Candidates Considered in Cost-Benefit Evaluation

Analysis Case (bold) SAMA Number and Title	Assumptions	CDF Reduction	PDR Reduction	OECR Reduction	Internal and External Benefit	Internal and External Benefit with Uncertainty	GGNS Cost Estimate	Conclusion
21. Increase Availability of Room Cooling	Eliminated failure of room cooling to LPCS, HPCS, SSW and safeguard switchgear battery rooms	22.9%	17.8%	18.2%	$175,400	$526,200		
29 – Provide a redundant train or means of ventilation	CNS estimate.						$2,202,725	Not cost effective
22. Increase Availability of the DG System Through HVAC Improvements	Eliminated failure of diesel generator rooms HVAC	9.2%	10.6%	8.5%	$75,988	$227,963		
30 – Add a diesel building high temperature alarm or redundant louver and thermostat.	CNS estimate.						$1,304,700	Not cost effective
32 – Diverse EDG HVAC logic	Cost for Phase II SAMAs 4 and 31 is used because the modifications are similar in scope.						$300,000	Not cost effective

Table E.2-2 (Continued)
Summary of Phase II SAMA Candidates Considered in Cost-Benefit Evaluation

Analysis Case (bold) SAMA Number and Title	Assumptions	CDF Reduction	PDR Reduction	OECR Reduction	Internal and External Benefit	Internal and External Benefit with Uncertainty	GGNS Cost Estimate	Conclusion
33 – Install additional fan and louver pair for EDG heating, ventilation, and air conditioning	CNS estimate.						$6,000,000	Not cost effective
23. Increased reliability of HPCI and RCIC room cooling	Eliminated failure of power to the HPCS pump room cooler. (RCIC pump continued operation is not dependent on room cooling.)	1.0%	1.6%	1.7%	$10,031	$30,093		
31 – Create ability to switch HPCI and RCIC room fan power supply to DC in an SBO event.	CNS estimate. Similar to SAMA 4, provide DC bus cross-ties.						$300,000	Not cost effective

Table E.2-2 (Continued)
Summary of Phase II SAMA Candidates Considered in Cost-Benefit Evaluation

Analysis Case (bold) SAMA Number and Title	Assumptions	CDF Reduction	PDR Reduction	OECR Reduction	Internal and External Benefit	Internal and External Benefit with Uncertainty	GGNS Cost Estimate	Conclusion
24. Increase Reliability of Instrument Air	Eliminated failure of the instrument air	14.9%	20.2%	21.3%	$137,842	$413,527		
34 – Modify procedure/hardware to provide ability to align diesel power to more air compressors	CNS estimate. More than just procedure.						$1,200,000	Not cost effective
35 – Replace service and instrument air compressors with more reliable compressors which have self-contained air cooling by shaft-driven fans	CNS estimate.						$1,394,598	Not cost effective
25. Backup Nitrogen to SRV	Eliminated operator failure to install air bottles	5.5%	3.7%	3.8%	$40,614	$121,841		
36 – Install nitrogen bottles as backup gas supply for safety relief valves.	Plant-specific cost estimate.						$1,722,706	Not cost effective

Table E.2-2 (Continued)
Summary of Phase II SAMA Candidates Considered in Cost-Benefit Evaluation

Analysis Case (bold) SAMA Number and Title	Assumptions	CDF Reduction	PDR Reduction	OECR Reduction	Internal and External Benefit	Internal and External Benefit with Uncertainty	GGNS Cost Estimate	Conclusion
26. Improve Availability of SRVs and MSIVs	Eliminated failure of non-ADS SRVs	46.1%	16.4%	16.1%	$300,631	$901,893		
37 – Improve SRV and MSIV pneumatic components.	CNS estimate.						$1,500,000	Not cost effective
27. Improve Suppression Pool Cooling	Eliminated the failure of flow to the RHR heat exchangers	18.5%	37.4%	39.9%	$205,223	$615,669		
38 – Install an independent method of suppression pool cooling.	CNS estimate.						$5,800,000	Not cost effective
28. Increase Availability of Containment Heat Removal	Eliminated failure of cooled flow from RHR pump A and B	26.6%	51.6%	54.7%	$288,437	$865,312		
39 – Procedural change to cross-tie open cycle cooling system to enhance containment spray system	Procedural range estimate.						$25,000	Retain

Table E.2-2 (Continued)
Summary of Phase II SAMA Candidates Considered in Cost-Benefit Evaluation

Analysis Case (bold) SAMA Number and Title	Assumptions	CDF Reduction	PDR Reduction	OECR Reduction	Internal and External Benefit	Internal and External Benefit with Uncertainty	GGNS Cost Estimate	Conclusion
41 – Use the fire water system as a backup source for the drywell spray system	Similar to Phase II SAMA 26, implement modifications to allow manual alignment of the fire water system to RHR heat exchangers.						$1,950,000	Not cost effective
29. Decay Heat Removal Capability – Drywell Spray	Eliminated failure of RHR spray	26.6%	51.6%	54.7%	$288,550	$865,649		
40 – Install a passive drywell spray system to provide redundant drywell spray method.	CNS estimate.						$5,800,000	Not cost effective
30. Increase Availability of the CST	Eliminated failure of HPCS and RCIC suction	11.3%	16.8%	17.4%	$107,899	$323,696		
42 – Enhance procedures to refill CST from demineralized water or service water system.	Procedure with engineering and training range estimate.						$200,000	Retain

Table E.2-2 (Continued)
Summary of Phase II SAMA Candidates Considered in Cost-Benefit Evaluation

Analysis Case (bold) SAMA Number and Title	Assumptions	CDF Reduction	PDR Reduction	OECR Reduction	Internal and External Benefit	Internal and External Benefit with Uncertainty	GGNS Cost Estimate	Conclusion
31. Filtered Vent to Increase Heat Removal Capacity for Non-ATWS Events	Reduced the baseline accident progression source terms by a factor of 2	0.0%	26.4%	34.3%	$80,920	$242,759		
43 – Install a filtered containment vent to provide fission product scrubbing	CNS estimate.						$1,500,000	Not cost effective
32. Reduce Hydrogen Ignition	Eliminated failure of hydrogen igniters	15.9%	20.7%	20.2%	$142,455	$427,365		
44 – Provide post-accident containment inerting capability.	Plant-specific cost estimate.						$2,665,123	Not cost effective
45 – Install a passive hydrogen control system.	Monticello (SAMA 10) estimated that this modification would cost ~$760,000.						$760,000	Not cost effective

Table E.2-2 (Continued)
Summary of Phase II SAMA Candidates Considered in Cost-Benefit Evaluation

Analysis Case (bold) SAMA Number and Title	Assumptions	CDF Reduction	PDR Reduction	OECR Reduction	Internal and External Benefit	Internal and External Benefit with Uncertainty	GGNS Cost Estimate	Conclusion
33. Controlled Containment Venting	Eliminated failure of air-operated valves to open	2.9%	5.4%	5.8%	$31,080	$93,240		
46 – Provide passive overpressure relief by changing the containment vent valves to fail open and improving the strength of the rupture disk	CNS estimate.						$1,000,000	Not cost effective
47 – Enable manual operation of all containment vent valves via local controls	Oyster Creek (SAMA 84) estimated that it would cost $150,000 to add handwheels in the reactor building to open AOVs in the current vent path.						$150,000	Not cost effective
34. ISLOCA	Removed all ISLOCA initiators	< 0.1%	< 0.1%	< 0.1%	$77	$231		
48 – Increase frequency of valve leak testing to reduce ISLOCA frequency	CNS estimate.						$100,000	Not cost effective

Table E.2-2 (Continued)
Summary of Phase II SAMA Candidates Considered in Cost-Benefit Evaluation

Analysis Case (bold) SAMA Number and Title	Assumptions	CDF Reduction	PDR Reduction	OECR Reduction	Internal and External Benefit	Internal and External Benefit with Uncertainty	GGNS Cost Estimate	Conclusion
50 – Revise EOPs to improve ISLOCA identification	CNS estimate.						$50,000	Not cost effective
51 – Improve operator training on ISLOCA coping	CNS estimate.						$112,000	Not cost effective
35. MSIV Design	Eliminated failure of the MSIVs to close or remain closed	1.0%	1.6%	1.7%	$10,031	$30,093		
49 – Improve MSIV design to decrease the likelihood of containment bypass scenarios.	CNS estimate.						$1,000,000	Not cost effective

Table E.2-2 (Continued)
Summary of Phase II SAMA Candidates Considered in Cost-Benefit Evaluation

Analysis Case (bold) SAMA Number and Title	Assumptions	CDF Reduction	PDR Reduction	OECR Reduction	Internal and External Benefit	Internal and External Benefit with Uncertainty	GGNS Cost Estimate	Conclusion
36. SLC System	Eliminated failure to initiate SLC and failures of alternate boron injection (ABI)	1.1%	1.7%	1.7%	$10,616	$31,849		
52 – Increase boron concentration in the SLC system [Reduced time required to achieve shutdown provides increased margin in the accident timeline for successful initiation of SLC]	CNS estimate.						$50,000	Not cost effective

Table E.2-2 (Continued)
Summary of Phase II SAMA Candidates Considered in Cost-Benefit Evaluation

Analysis Case (bold) SAMA Number and Title	Assumptions	CDF Reduction	PDR Reduction	OECR Reduction	Internal and External Benefit	Internal and External Benefit with Uncertainty	GGNS Cost Estimate	Conclusion
37. SRV Reseat	Eliminated the initiator for SRVs inadvertently being open and basic events for stuck open SRVs	3.1%	4.3%	4.5%	$29,108	$87,324		
53 – Increase safety relief valve (SRV) reseat reliability to address the risk associated with dilution of boron caused by the failure of the SRVs to reseat after standby liquid control (SLC) injection	CNS estimate.						$2,200,000	Not cost effective
38. Add Fire Suppression[1]	Eliminated fire CDF from the critical switchgear rooms.	n/a	n/a	n/a	$34,115	$102,345		
54 – Add automatic fire suppression systems to the dominant fire zones	CNS estimate.						$375,000	Not cost effective

Table E.2-2 (Continued)
Summary of Phase II SAMA Candidates Considered in Cost-Benefit Evaluation

Analysis Case (bold) SAMA Number and Title	Assumptions	CDF Reduction	PDR Reduction	OECR Reduction	Internal and External Benefit	Internal and External Benefit with Uncertainty	GGNS Cost Estimate	Conclusion
39. Reduce Risk from Fires that Require Control Room Evacuation[(1)]	Eliminate fire CDF from the main control room.	n/a	n/a	n/a	$140,174	$420,521		
55 – Upgrade the ASDS panel to include additional system controls for opposite division.	CNS estimate.						$786,991	Not cost effective
40. Large Break LOCA	Eliminated Large Break LOCA	7.1%	16.5%	17.5%	$316,124	$948,372		
56 – Provide digital large break LOCA protection to identify symptoms/precursors of a large break LOCA (a leak before break)	Duane Arnold estimated that this modification would cost at least $2M.						$2,000,000	Not cost effective

Table E.2-2 (Continued)
Summary of Phase II SAMA Candidates Considered in Cost-Benefit Evaluation

Analysis Case (bold) SAMA Number and Title	Assumptions	CDF Reduction	PDR Reduction	OECR Reduction	Internal and External Benefit	Internal and External Benefit with Uncertainty	GGNS Cost Estimate	Conclusion
41. Trip/Shutdown Risk	Reducing all initiating events except pipe breaks, floods, and LOSP by a factor of 2	8.0%	6.7%	6.9%	$62,372	$187,117		
57 – Generation Risk Assessment implementation into plant activities (trip/ shutdown risk modeling).	CNS estimate.						$500,000	Not cost effective
42. Increase Availability of SSW Pump House Ventilation System	Eliminated failure of SSW Pump House Ventilation	1.6%	2.2%	2.3%	$15,071	$45,212		
58 – Increase the training emphasis and provide additional control room indication on the operational status of SSW pump house ventilation system.	Hardware modification range estimate.						$100,000	Not cost effective

Table E.2-2 (Continued)
Summary of Phase II SAMA Candidates Considered in Cost-Benefit Evaluation

Analysis Case (bold) SAMA Number and Title	Assumptions	CDF Reduction	PDR Reduction	OECR Reduction	Internal and External Benefit	Internal and External Benefit with Uncertainty	GGNS Cost Estimate	Conclusion
43. Increase recovery time of ECCS upon loss of SSW	Eliminated failure of SSW to the LPCS room cooler	4.1%	6.5%	6.8%	$40,452	$121,357		
59 – Increase operator training for alternating operation of the low pressure ECCS pumps (LPCI and LPCS) for loss of SSW scenarios.	Procedure with training range estimate.						$50,000	Retain
44. Additional Containment Heat Removal	Eliminated failure of suppression pool cooling and containment spray systems	27.5%	53.2%	56.3%	$298,121	$894,362		
60 – Install an additional method of heat removal from containment.	Plant-specific cost estimate.						$4,352,023	Not cost effective

Table E.2-2 (Continued)
Summary of Phase II SAMA Candidates Considered in Cost-Benefit Evaluation

Analysis Case (bold) SAMA Number and Title	Assumptions	CDF Reduction	PDR Reduction	OECR Reduction	Internal and External Benefit	Internal and External Benefit with Uncertainty	GGNS Cost Estimate	Conclusion
45. Improve RHR Heat Exchanger Availability	Eliminated failure of RHR HX Cooler inlet and outlet valves	3.6%	7.8%	8.3%	$41,340	$124,019		
62 – Add a bypass around the RHR HX inlet and outlet valves	Plant-specific cost estimate.						$2,831,652	Not cost effective
46. Improve RCIC Lube Oil Cooling	Eliminated the failure to cool RCIC lube oil	4.7%	1.9%	1.6%	$30,894	$92,683		
63 – Add a redundant RCIC lube oil cooling path.	Hardware modification range estimate.						$100,000	Not cost effective

1. These analysis cases only impact external events and have been evaluated differently as shown in Section E.2.3.

Table E.2-3
Sensitivity Analysis Results

Analysis Case (bold) SAMA Number and Title	Internal and External Benefit, 20 yrs Remaining, 7% Discount Rate	Sensitivity Case 1, Internal and External Benefit, 33 yrs Remaining, 7% Discount Rate	Sensitivity Case 2, Internal and External Benefit, 20 yrs Remaining, 3% Discount Rate	GGNS Cost Estimate
1. DC Power	$115,656	$171,775	$144,423	
1 – Provide additional DC battery capacity				$500,000
2 – Replace lead-acid batteries with fuel cells				$1,000,000
11 – Portable generator for direct current (DC) power: This SAMA involves the use of a portable generator to supply DC power to the battery chargers during a station blackout.				$714,000
12 – Portable generator for direct current (DC) power: This SAMA involves the use of a portable generator to supply DC power to the individual panels during a station blackout.				$714,000
15 – Use DC generators to provide power to operate the switchyard power control breakers while a 480-V AC generator could supply the air compressors for breaker support.				$1,428,000
2. Improve Charger Reliability	$13,598	$19,619	$17,276	
3 – Add battery charger to existing DC system				$90,000
13 – Proceduralize battery charger high-voltage shutdown circuit inhibit				$50,000
3. Add DC System Cross-Ties	$73,056	$105,875	$92,577	
4 – Provide DC bus cross-ties				$300,000

Table E.2-3 (Continued)
Sensitivity Analysis Results

Analysis Case (bold) SAMA Number and Title	Internal and External Benefit, 20 yrs Remaining, 7% Discount Rate	Sensitivity Case 1, Internal and External Benefit, 33 yrs Remaining, 7% Discount Rate	Sensitivity Case 2, Internal and External Benefit, 20 yrs Remaining, 3% Discount Rate	GGNS Cost Estimate
4. Increase Availability of On-Site AC Power	$149,396	$221,380	$186,814	
5 – Provide an additional diesel generator				$20,000,000
8 – Install a gas turbine generator with tornado protection				$2,000,000
5. Improve AC Power	$177,524	$262,069	$222,495	
6 – Improve 4.16-kV bus cross-tie ability				$656,000
17 – Provide alternate feeds to essential loads directly from an alternate emergency bus				$656,000
6. Reduce Loss of Off-Site Power During Severe Weather	$26,087	$38,786	$32,554	
7 – Install an additional, buried off-site power source.				$2,485,000
7. Provide Backup EDG Cooling	$16,515	$24,490	$20,642	
9 – Use fire water system as backup source for diesel cooling				$100,000
10 – Add new backup source of diesel cooling				$2,000,000
8. Increase EDG Reliability	$30,348	$44,328	$38,279	
14 – Provide a portable EDG fuel oil transfer pump				$100,000

Table E.2-3 (Continued)
Sensitivity Analysis Results

Analysis Case (bold) SAMA Number and Title	Internal and External Benefit, 20 yrs Remaining, 7% Discount Rate	Sensitivity Case 1, Internal and External Benefit, 33 yrs Remaining, 7% Discount Rate	Sensitivity Case 2, Internal and External Benefit, 20 yrs Remaining, 3% Discount Rate	GGNS Cost Estimate
9. Improve DG reliability	$2,181	$3,249	$2,718	
16 – Provide a diverse swing diesel generator air start compressor				$100,000
10. Reduce Plant-Centered Loss of Off-Site Power	$76,556	$113,849	$95,522	
18 – Protect transformers from failure				$780,000
11. Redundant Power to Torus Hard Pipe Vent (THPV) Valves	$10,766	$15,502	$13,694	
19 – Provide redundant power to direct torus hard pipe vent valves to improve the reliability of the direct torus vent valves and enhance the containment heat removal capability.				$714,000
12. High Pressure Injection System	$594,912	$901,576	$733,645	
20 – Install an independent active or passive high pressure injection system				$8,800,000
61 – Install a backup water supply and pumping capability that is independent of normal and emergency AC power				$6,409,949

Table E.2-3 (Continued)
Sensitivity Analysis Results

Analysis Case (bold) SAMA Number and Title	Internal and External Benefit, 20 yrs Remaining, 7% Discount Rate	Sensitivity Case 1, Internal and External Benefit, 33 yrs Remaining, 7% Discount Rate	Sensitivity Case 2, Internal and External Benefit, 20 yrs Remaining, 3% Discount Rate	GGNS Cost Estimate
13. Extend RCIC Operation	$10,031	$14,448	$12,757	
21 – Raise HPCI/RCIC backpressure trip set points [HPCI backpressure trip setpoint has already been raised. This SAMA will evaluate raising the RCIC backpressure trip set point].				$200,000
14. Improve ADS System	$299,106	$469,925	$360,320	
22 – Modify automatic depressurization system components to improve reliability [This SAMA will add larger accumulators thus increasing reliability during SBOs].				$1,176,850
15. Improve ADS Signals	$129,383	$205,503	$154,719	
23 – Add signals to open safety relief valves automatically in an MSIV closure transient.				$1,500,000
16. Low Pressure Injection System	$229,965	$331,005	$292,574	
24 – Add a diverse low pressure injection system.				$8,800,000
17. ECCS Low Pressure Interlock	$10,031	$14,448	$12,757	
25 – Install a bypass switch to allow operators to bypass the low reactor pressure interlock circuitry that inhibits opening the LPCI or core spray injection valves following sensor or logic failures that prevent all low pressure injection valves from opening.				$1,000,000

Table E.2-3 (Continued)
Sensitivity Analysis Results

Analysis Case (bold) SAMA Number and Title	Internal and External Benefit, 20 yrs Remaining, 7% Discount Rate	Sensitivity Case 1, Internal and External Benefit, 33 yrs Remaining, 7% Discount Rate	Sensitivity Case 2, Internal and External Benefit, 20 yrs Remaining, 3% Discount Rate	GGNS Cost Estimate
18. RHR Heat Exchangers	$205,223	$290,595	$263,557	
26 – Implement modifications to allow manual alignment of the fire water system to RHR heat exchangers.				$1,950,000
19. Emergency Service Water System Reliability	$37,903	$54,031	$48,491	
27 – Add a service water pump to increase availability of cooling water				$5,900,000
20. Main Feedwater System Reliability	$162,050	$241,055	$202,163	
28 – Add a motor-driven feed water pump				$1,650,000
21. Increase Availability of Room Cooling	$175,400	$265,739	$216,342	
29 – Provide a redundant train or means of ventilation				$2,202,725
22. Increase Availability of the DG System through HVAC Improvements	$75,988	$113,283	$94,669	
30 – Add a diesel building high temperature alarm or redundant louver and thermostat.				$1,304,700
32 – Diverse EDG HVAC logic				$300,000
33 – Install additional fan and louver pair for EDG heating, ventilation, and air conditioning				$6,000,000

Table E.2-3 (Continued)
Sensitivity Analysis Results

Analysis Case (bold) SAMA Number and Title	Internal and External Benefit, 20 yrs Remaining, 7% Discount Rate	Sensitivity Case 1, Internal and External Benefit, 33 yrs Remaining, 7% Discount Rate	Sensitivity Case 2, Internal and External Benefit, 20 yrs Remaining, 3% Discount Rate	GGNS Cost Estimate
23. Increased Reliability of HPCI and RCIC Room Cooling	$10,031	$14,448	$12,757	
31 – Create ability to switch HPCI and RCIC room fan power supply to DC in an SBO event.				$300,000
24. Increase Reliability of Instrument Air	$137,842	$201,172	$173,951	
34 – Modify procedure/hardware to provide ability to align diesel power to more air compressors				$1,200,000
35 – Replace service and instrument air compressors with more reliable compressors which have self-contained air cooling by shaft-driven fans				$1,394,598
26. Backup Nitrogen to SRV	$40,614	$62,050	$49,828	
36 – Install nitrogen bottles as backup gas supply for safety relief valves.				$1,722,706
26. Improve Availability of SRVs and MSIVs	$300,631	$472,257	$362,190	
37 – Improve SRV and MSIV pneumatic components.				$1,500,000
27. Improve Suppression Pool Cooling	$205,223	$290,595	$263,557	
38 – Install an independent method of suppression pool cooling.				$5,800,000

Table E.2-3 (Continued)
Sensitivity Analysis Results

Analysis Case (bold) SAMA Number and Title	Internal and External Benefit, 20 yrs Remaining, 7% Discount Rate	Sensitivity Case 1, Internal and External Benefit, 33 yrs Remaining, 7% Discount Rate	Sensitivity Case 2, Internal and External Benefit, 20 yrs Remaining, 3% Discount Rate	GGNS Cost Estimate
28. Increase Availability of Containment Heat Removal	$288,437	$409,794	$369,722	
39 – Procedural change to cross-tie open cycle cooling system to enhance containment spray system				$25,000
41 – Use the fire water system as a backup source for the drywell spray system				$1,950,000
29. Decay Heat Removal Capability – Drywell Spray	$288,550	$409,953	$369,866	
40 – Install a passive drywell spray system to provide redundant drywell spray method.				$5,800,000
30. Increase Availability of the CST	$107,899	$156,536	$136,643	
42 – Enhance procedures to refill CST from demineralized water or service water system.				$200,000
31. Filtered Vent to Increase Heat Removal Capacity for Non-ATWS Events	$80,920	$96,745	$113,074	
43 – Install a filtered containment vent to provide fission product scrubbing				$1,500,000
32. Reduce Hydrogen Ignition	$142,455	$209,206	$179,104	
44 – Provide post-accident containment inerting capability.				$2,665,123
45 – Install a passive hydrogen control system.				$760,000

**Table E.2-3 (Continued)
Sensitivity Analysis Results**

Analysis Case (bold) SAMA Number and Title	Internal and External Benefit, 20 yrs Remaining, 7% Discount Rate	Sensitivity Case 1, Internal and External Benefit, 33 yrs Remaining, 7% Discount Rate	Sensitivity Case 2, Internal and External Benefit, 20 yrs Remaining, 3% Discount Rate	GGNS Cost Estimate
33. Controlled Containment Venting	$31,080	$44,274	$39,779	
46 – Provide passive overpressure relief by changing the containment vent valves to fail open and improving the strength of the rupture disk				$1,000,000
47 – Enable manual operation of all containment vent valves via local controls				$150,000
34. ISLOCA	$77	$118	$95	
48 – Increase frequency of valve leak testing to reduce ISLOCA frequency				$100,000
50 – Revise EOPs to improve ISLOCA identification				$50,000
51 – Improve operator training on ISLOCA coping				$112,000
35. MSIV Design	$10,031	$14,448	$12,757	
49 – Improve MSIV design to decrease the likelihood of containment bypass scenarios.				$1,000,000
36. SLC System	$10,616	$15,376	$13,458	
52 – Increase boron concentration in the SLC system [Reduced time required to achieve shutdown provides increased margin in the accident timeline for successful initiation of SLC]				$50,000

Table E.2-3 (Continued)
Sensitivity Analysis Results

Analysis Case (bold) SAMA Number and Title	Internal and External Benefit, 20 yrs Remaining, 7% Discount Rate	Sensitivity Case 1, Internal and External Benefit, 33 yrs Remaining, 7% Discount Rate	Sensitivity Case 2, Internal and External Benefit, 20 yrs Remaining, 3% Discount Rate	GGNS Cost Estimate
37. SRV Reseat	$29,108	$42,416	$36,767	
53 – Increase safety relief valve (SRV) reseat reliability to address the risk associated with dilution of boron caused by the failure of the SRVs to reseat after standby liquid control (SLC) injection				$2,200,000
38. Add Fire Suppression[1]	N/A	N/A	N/A	
54 – Add automatic fire suppression systems to the dominant fire zones				$375,000
39. Reduce Risk from Fires that Require Control Room Evacuation[1]	N/A	N/A	N/A	
55 – Upgrade the ASDS panel to include additional system controls for opposite division.				$786,991
40. Large Break LOCA	$316,124	$463,652	$380,827	
56 – Provide digital large break LOCA protection to identify symptoms/precursors of a large break LOCA (a leak before break)				$2,000,000
41. Trip/Shutdown Risk	$62,372	$94,032	$77,170	
57 – Generation Risk Assessment implementation into plant activities (trip/shutdown risk modeling).				$500,000

Table E.2-3 (Continued)
Sensitivity Analysis Results

Analysis Case (bold) SAMA Number and Title	Internal and External Benefit, 20 yrs Remaining, 7% Discount Rate	Sensitivity Case 1, Internal and External Benefit, 33 yrs Remaining, 7% Discount Rate	Sensitivity Case 2, Internal and External Benefit, 20 yrs Remaining, 3% Discount Rate	GGNS Cost Estimate
42. Increase Availability of SSW Pump House Ventilation System	$15,071	$21,998	$19,017	
58 – Increase the training emphasis and provide additional control room indication on the operational status of SSW pump house ventilation system.				$100,000
43. Increase Recovery Time of ECCS upon Loss of SSW	$40,452	$58,438	$51,357	
59 – Increase operator training for alternating operation of the low pressure ECCS pumps (LPCI and LPCS) for loss of SSW scenarios.				$50,000
44. Additional Containment Heat Removal	$298,121	$423,739	$382,038	
60 – Install an additional method of heat removal from containment.				$4,352,023
45. Improve RHR Heat Exchanger Availability	$41,340	$58,200	$53,263	
62 – Add a bypass around the RHR HX inlet and outlet valves				$2,831,652
46. Improve RCIC Lube Oil Cooling	$30,894	$48,447	$37,264	
63 – Add a redundant RCIC lube oil cooling path.				$100,000

1. These analysis cases only impact external events and have been evaluated differently as shown in Section E.2.3.