Appendix F

Severe Accident Mitigation Alternatives Analysis
Rev. 2

Braidwood Station Environmental Report

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Acronyms Used in Attachment F

AF	auxiliary feedwater
AFW	auxiliary feedwater
AOT	allowable outage time
AMSAC	anticipated transient without scram mitigating system actuation circuitry
AP	auxiliary power
ASME	American Society of Mechanical Engineers
ATWS	anticipated transient without scram
CC	component cooling water
CCF	common cause failure
CCP	centrifugal charging pump
CCW	component cooling water
CDF	core damage frequency
CET	containment event tree
CF	containment failure
CHR	containment heat removal
CIS	containment isolation system
COP	containment overpressurization
CPI	consumer price index
CS	containment spray
CST	condensate storage tank
CV	chemical and volume control system
CVCS	chemical and volume control system
DCH	direct containment heating
DG	diesel generator
DMS	diverse mitigation system
DOE	Department of Energy
ECCS	emergency core cooling system
EDG	emergency diesel generator
EE	external events
EFPD	effective full power days
EPRI	Electric Power Research Institute
EPZ	emergency planning zone
ESF	engineered safety features
ESFAS	engineered safety features actuation system

Acronyms Used in Attachment F

ETE	evacuation time estimate
F&O	fact and observation
FP	fire protection
FPIE	full power internal events
F-V	Fussell-Vesely
FW	feedwater
GE	general emergency
HCLPF	high confidence of low probability of failure
HEP	human error probability
HPI	high pressure injection
HRA	human reliability analysis
HVAC	heating ventilation and air-conditioning
HX	heat exchanger
IA	instrument air
IE	initiating event
IPE	individual plant examination
IPEEE	individual plant examination – external events
ISGTR	induced steam generator tube rupture
ISLOCA	interfacing system LOCA
JHEP	joint human error probability
LCO	limiting conditions of operation
LERF	large early release frequency
LMFW	loss of main feedwater
LOCA	loss of coolant accident
LOOP	loss of off-site power
MAAP	modular accident analysis program
MACCS2	MELCOR accident consequences code system, version 2
MACR	maximum averted cost-risk
MCC	motor control center
MCR	main control room
MDAFW	motor-driven auxiliary feedwater
MFW	main feedwater
MOV	motor operated valve
MSPI	mitigating systems performance index

Acronyms Used in Attachment F

MUR	measurement uncertainty recapture
NEI	Nuclear Energy Institute
NRC	U.S. Nuclear Regulatory Commission
OECR	off-site economic cost risk
PDP	positive displacement pump
PDS	plant damage state
PGA	peak ground acceleration
PI-SGTR	pressure induced steam generator tube rupture
PMF	probable maximum flooding
PMP	probable maximum precipitation
PORV	power operated relief valve
PRA	probabilistic risk analysis
PSA	probabilistic safety assessment
PWR	pressurized water reactor
RAI	request for additional information
RCFC	reactor containment fan coolers
RCP	reactor coolant pump
RCS	reactor coolant system
RDR	real discount rate
RHR	residual heat removal
RLE	review level earthquake
RPS	reactor protection system
RPV	reactor pressure vessel
RRW	risk reduction worth
RWST	refueling water storage tank
SAMA	severe accident mitigation alternative
SBO	station blackout
SG	steam generator
SGTR	steam generator tube rupture
SI	safety injection
SLB	steam line break
SLOCA	small loss of coolant accident
SOARCA	state of the art consequences analysis
SR	supporting requirement

Acronyms Used in Attachment F

SRP	standard review plan
SSPS	solid state protection system
SX	essential service water
TI-SGTR	thermally induced steam generator tube rupture
TS	technical specification
URE	updating requirement evaluation
VA	auxiliary building HVAC
VB	vessel breach
VCT	volume control tank
WS	normal service water

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SEVERE ACCIDENT MITIGATION ALTERNATIVES

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

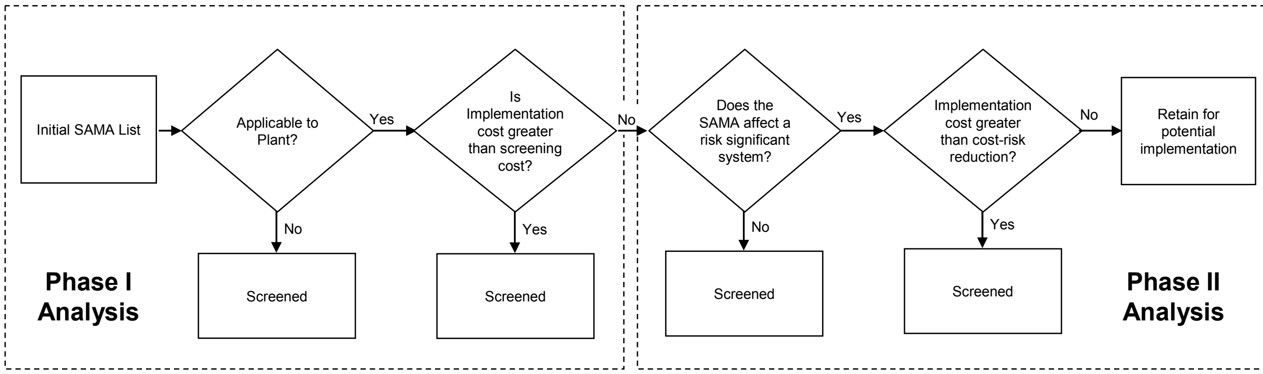
F.1 METHODOLOGY

The methodology selected for this analysis is contained in NEI 05-01, Severe Accident Mitigation Alternatives (SAMA) Analysis Guidance Document (NEI 2005), which has been reviewed and endorsed by the U.S. Nuclear Regulatory Commission (NRC). It involves identifying SAMA candidates that have potential for reducing plant risk and determining whether or not the implementation of those candidates is beneficial on a cost-risk reduction basis. The metrics chosen to represent plant risk include the core damage frequency (CDF), the dose-risk, and the offsite economic cost-risk. These values provide a measure of both the likelihood and consequences of a core damage event.

The SAMA process consists of the following steps:

- Braidwood Station (Braidwood) Probabilistic Risk Assessment (PRA) Model – Use the Braidwood Internal Events PRA model as the basis for the analysis (Section F.2). Incorporate External Events contributions as described in Section F.4.6.2.
- Level 3 PRA Analysis – Use the Braidwood Level 1 and 2 Internal Events PRA output and site-specific meteorology, demographic, land use, and emergency response data as input in performing a Level 3 PRA using the MELCOR Accident Consequences Code System Version 2 (MACCS2) (Section F.3). Incorporate External Events contributions as described in Section F.4.6.2.
- Baseline Risk Monetization – Use U.S. Nuclear Regulatory Commission (NRC) regulatory analysis techniques to calculate the monetary value of the unmitigated Braidwood severe accident risk. This becomes the maximum averted cost-risk that is possible (Section F.4).
- Phase 1 SAMA Analysis – Identify potential SAMA candidates based on the Braidwood Probabilistic Risk Assessment (PRA) (including the current fire model), Individual Plant Examination – External Events (IPEEE), and documentation from the industry and the NRC. Screen out SAMA candidates that are not applicable to the Braidwood design or are of low benefit in pressurized (PWRs) such as Braidwood, candidates that have already been implemented at Braidwood or whose benefits have been achieved at Braidwood using other means, and candidates whose estimated cost exceeds the maximum possible averted cost-risk (Section F.5).
- Phase 2 SAMA Analysis – Calculate the risk reduction attributable to each of the remaining SAMA candidates and compare to the estimated cost of implementation to identify the net cost-benefit. PRA insights are also used to screen SAMA candidates in this phase (Section F.6).
- Sensitivity Analysis – Evaluate how changes in the SAMA analysis assumptions might affect the cost-benefit evaluation (Section F.7).
- Conclusions – Summarize results and identify conclusions (Section F.8).

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



SAMA Screening Process

F.2 BRAIDWOOD PRA MODEL

The SAMA analysis is based upon Braidwood PRA model BB011b1, which includes an integrated internal flooding analysis, but not internal fires, seismic events, or other external events. The original Braidwood PRA was submitted to the NRC to satisfy the requirements of NRC Generic Letter 88-20 (NRC 1989). Since the original Individual Plant Examination (IPE) submittal to the NRC in June 1994 (ComEd 1994), a Modified IPE was submitted in March 1997 (ComEd 1997a). The Modified IPE answered requests for additional information (RAI) from the NRC relative to the original IPE and incorporated plant procedure changes and modifications. The PRA was developed from the Modified IPE and since that time, it has been updated on numerous occasions to maintain consistency with the operating plant and to reflect the latest PRA technology.

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

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

Sections F.4.6.2 and F.5.1.6 provide a description of the process used to integrate external events contributions into the Braidwood SAMA process.

F.2.1 PRA MODEL CHANGES SINCE THE IPE/IPEEE

Compared with the IPE, the current PRA includes more current equipment availability and reliability data as well as any subsequent plant configuration changes that have had an impact on the risk profile. In addition to updating the data and plant and procedure changes, the model was converted from a support state model to a single top fault tree model. Over the course of multiple updates, there were many changes to PRA models and databases in each element of the PRA. These changes included:

- Revision of the definition of core damage and the success criteria
- Changes in the selection of initiating events and revision of initiating event frequencies
- Complete revisions to event tree analysis
- Enhancements and additions of system fault trees
- Enhanced treatment of offsite power recovery
- Upgraded PRA reliability database with plant-specific information
- Revision to common cause failures (CCF) and the CCF data

- Revision to treatment of human actions
- Revised internal flooding analyses

Table F.2-1 provides a summary of the model revision history, including a description of the major update issues for each revision.

F.2.2 LEVEL 1 MODEL OVERVIEW

The Braidwood Level 1 PRA model includes a comprehensive treatment of accident sequences producing core damage from internal events at full power, including internal flooding. The frequency of all sequences for which reactor core cooling performance degrades beyond this point is defined as the Core Damage Frequency (CDF). The annual average CDF for each of the Braidwood units from the current analysis is shown in the following table.

CDF RESULTS FOR BRAIDWOOD UNITS 1 AND 2 (BB011b1)

Unit	CDF	Truncation Limit
Braidwood Unit 1	3.57E-5	1.0E-10
Braidwood Unit 2	3.51E-5	1.0E-10

The BB011b1 model, which was used to support the SAMA evaluation, was released to document the replacement of the "LERF only" model in the BB011b PRA with the WCAP-16341-P Level 2 model. The Level 1 portions of the BB011b and BB011b1 models are the same. The discussion in F.2.2 describes the Level 1 model that is common to both the BB011b and BB011b1 models.

The leading causes of core damage are described in the following sections.

The freeze date for the inclusion of plant specific data for the model was December 2010. A specific freeze date for physical changes is more difficult to establish given that issues are tracked in a database and addressed based on the priority of the change and the resources available. It is possible that recent risk significant changes have been incorporated in the BB011b/BB011b1 model while the incorporation of older, non-risk significant changes has been deferred until a later model update.

For internal events contributors, the differences between the units are minor and are documented in the PRA system notebook. For the purposes of the SAMA analysis, the Unit 1 model is used as the quantification basis and considered to be representative of both units. For the fire contributors, there are differences in the units which translate to measurable differences in plant risk. For the SAMA analysis, the SAMA identification process was performed separately for each unit (refer to section F.5.1.6.1) to account for the differences. For SAMA quantification, the external events multiplier was based on the larger of the two units' CDF values (section F.4.6.2) and for quantification of fire specific SAMAs, the contributions from the unit specific fire zones were used (section F.6).

F.2.2.1 CONTRIBUTION TO CDF BY INITIATING EVENT

Initiating event contributions to the CDF profile are shown in figures F.2-1 and F.2-2. Details of the highest ranking initiating event contributions are briefly described below. The equipment failures or failures of operator actions which would produce core damage are highlighted.

Loss of Essential Service Water: Loss of Essential Service Water (SX) contributes between 36% and 37% to the CDF. In model BB011b/BB011b1, the absolute value of Loss of SX actually decreased slightly, but increased as a percentage of CDF due to greater decreases in other initiating events.

One set of important cutsets includes a loss of SX (e.g., due to common cause failure of all SX pumps) with failure of the operators to execute main feedwater restoration. Previously, such events were addressed by use of the diesel-driven auxiliary feedwater (AFW) pump, but new restrictions that require a running SX pump to prevent unintended recirculation and overheating of the diesel AFW pump now fail the diesel AFW pump on loss of all SX pumps.

Another important set of cutsets also applies to loss of SX scenarios, but includes operator action dependencies. Loss of SX initiated by loss of a running pump requires operator actions to restore SX by starting the opposite SX pump, cross-tying to the opposite unit, or providing an alternate cooling and suction source to the chemical and volume control (CV) pumps in order to maintain reactor coolant pump (RCP) seal cooling. If the RCP seal loss of coolant accident (LOCA) occurs, the loss of SX also inhibits the ability to remove decay heat during eventual recirculation operations, leading to core damage. Modeling of these sequences includes dependencies among these operator actions and credit for delayed recovery of SX and/or seal cooling.

The contribution of Loss of SX events remains high due to the high probability of an RCP Seal LOCA following a loss of SX. Loss of SX remains a challenging event even if there is not an RCP Seal LOCA as it is vital support to numerous systems (e.g., AF and room cooling for CV, residual heat removal (RH), and the emergency diesel generators (EDGs)).

Loss of SX leads to a loss of both sources of RCP seal cooling. The RCP thermal barriers are cooled by the Component Cooling Water (CC) System, and RCP seal injection is provided by the CV pumps. SX serves as the ultimate heat sink for CC as well as providing oil and room cooling for the CV pumps. Without cooling, temperature induced degradation of the RCP seals may lead to a Seal LOCA event (1 in 5 probability), which is then modeled as a Small LOCA. Loss of SX also fails or degrades much of the key safety equipment needed to maintain primary inventory control. With CV and safety injection (SI) pumps failed due to cooling dependencies on SX, high-pressure primary makeup is unavailable. Continuing primary leakage leads to eventual core damage. The alternate means of cooling the CV pump lube oil coolers from the fire protection (FP) system and the switching of the CV pump intake to the cooler refueling water storage tank (RWST) are important actions in reducing the importance of loss of SX events.

Small LOCA: Small LOCA contributes about 18% to the CDF. Small LOCAs are leaks in the reactor coolant system pressure boundary into the containment with nominal leak rates that are equivalent to those which would be produced by ideal break sizes from about ½ inch to 2 inches in diameter. These include small pipe failures, failures in other pressure boundary components such as RCP seals, and leaks from the pressurizer relief, head vent, and pressurizer safety valves. These leak sources are generally separated into isolable and non-isolable sources. Note that this section discusses the importance of LOCAs from an initiating event perspective. Consequential RCP Seal LOCAs (i.e., failures due to a result of loss of seal injection and cooling), are not discussed in this category, since they are not Small LOCA initiating events, but are modeled as consequential Small LOCAs.

Small LOCAs, which are typically major contributors to PWR PRA results, have a high contribution to CDF due to the multiple mitigation systems required to function to prevent core damage. Since the leak size is not large enough to remove decay heat from the core, decay heat must be removed through the Steam Generators using the Auxiliary Feedwater Pumps, the Startup Feedwater Pump, or Motor Driven Feedwater Pump. Reactor coolant system (RCS) inventory must also be maintained using emergency core cooling system (ECCS) Injection. Use of the Motor Driven and Startup Feedwater Pumps as a backup to the AF Pumps is hindered since the Safety Injection Signal isolates the Main Feedwater System. Small LOCAs are significantly more likely to occur than larger LOCAs.

In Revision 6F, new cutsets included a LOCA with failure of the RH pumps and/or heat exchangers due to their dependence on CC. Small LOCAs are the most likely, so appear with the greatest frequency, but other LOCAs (including consequential LOCAs) also appear in the results. In addition, Braidwood results contain cutsets that include the need to manipulate the SX007 valves for any event that requires cold leg recirculation, such as LOCAs. Modeling of a new operator action to manipulate the SX007 valves on loss of power and related improvements in the modeling of the existing operator actions to manipulate the SX007 valves reduce the contribution of Small LOCAs for Revision BB011b/BB011b1.

Internal Flooding: Internal Flooding sequences contribute 16% to CDF. Overall, the dominant internal flood scenario for CDF involves a rupture of the Fire Protection system within the common areas of the radiological controlled area of the Auxiliary Building. These particular flood scenarios account for about two-thirds of the total internal flood contribution to CDF.

Loss of Component Cooling Water: Loss of Component Cooling Water (CCW) contributes about 9% of CDF with this revision. Several of the minor model changes reduced the contribution of Loss of CCW events, including the modeling of recovery action to align and start the 0CC pump, removal of extraneous common cause failure terms, addition of Loss of CCW initiating events as exclusions to split CC train operation, and correction of some dependent human failure probabilities.

Loss of Auxiliary Electric Power (AP): This initiating event category contributes approximately 4-6% of the total CDF. These initiating events represent failures of an AP power source to a running component, which then leads to a plant transient. The most important AP failures as initiating events lead to a Loss of SX or Loss of CCW, which are discussed above.

Steam Generator Tube Rupture: This initiating event category represents 4-5% of CDF. As with Small LOCAs, Steam Generator Tube Ruptures (SGTRs) require both Auxiliary Feedwater for Decay Heat Removal and ECCS Injection for RCS Inventory Control. Mitigation of this event is further complicated by the need to identify and isolate the ruptured Steam Generator. In the highest-ranking SGTR sequences, the operators fail to identify and isolate the ruptured steam generator and/or fail to depressurize and cooldown the RCS. If both actions fail, then core damage occurs due to the loss of RCS inventory from the affected steam generator (SG). If the ruptured SG is not isolated or the RCS depressurization / cooldown occurs late in the scenario, the steam generator is overfilled, the power operated relief valves (PORVs) are challenged, and pass liquid. The PORVs are then assumed to fail to fully close. In these scenarios, residual heat removal (RHR) is required for long term cooling, and its failure leads to core damage.

Medium LOCA: Medium LOCAs contribute to approximately 4% of CDF. The effects of Medium LOCAs are similar to those discussed for Small LOCAs, with the exception of the need for Auxiliary Feedwater. The cutsets seen for Small LOCAs also appear for Medium LOCAs, but are combined with the lower frequency of the Medium LOCA.

General Transients & LMFW: This initiating event category, which includes general reactor trips and losses of main feedwater, accounts for approximately 2% of the total CDF. The General Transient scenarios involve a failure of steam generator heat removal via auxiliary feedwater (AF system failures), followed by the operator failing to re-establish main feedwater using the startup or motor-driven feedwater pumps, followed by failure of bleed and feed cooling. The relatively high frequency of general transient initiating events (as compared to other initiating events) is the primary cause for the importance of this initiator.

Other Transients: This group of events contributes approximately 5% of the CDF. The most significant events are Loss of Offsite Power, Loss of a 125V DC Bus, and interfacing system loss of coolant accidents (ISLOCAs). Each of the contributing initiating events in this group comprises less than 2% of CDF.

RCP Seal LOCA: Also shown in Figures F.2-1 and F.2-2 is the contribution of RCP Seal LOCA to the CDF results for Braidwood; RCP Seal LOCAs account for just under half of the total CDF. A majority of the RCP Seal LOCA CDF originates from Loss of SX or Internal Flood initiating events. These initiators are described previously. Loss of Offsite Power and Loss of Component Cooling Water initiators also contribute to the importance of the RCP seals.

F.2.2.2 TOP RANKING ACCIDENT SEQUENCES

The top ranked accident sequences are discussed in Table F.2-2. Examining the top accident sequences provides another perspective on the contributors to CDF. The Braidwood PRA consists of ten (10) event trees, which contain more than 100 accident sequences. About 12 sequences contribute to 99% of the total CDF. Table F.2-2 presents the “significant” accident sequences according the definition used in the American Society of Mechanical Engineers (ASME) PRA Standard, which includes all sequences in the top 95% of CDF and any individual sequences contributing more than 1%. The top 10 accident sequences comprise about 97% of the total CDF.

F.2.2.3 RISK IMPORTANCE OF BRAIDWOOD SYSTEMS

The Fussell-Vesely (F-V) importance measures evaluated from the Braidwood Unit 1 CDF model are used to evaluate one aspect of risk importance. F-V has been chosen to represent risk importance because it includes consideration of the impact of both initiating events and mitigation capability. Since failure or unavailability of a system may play a role in causing an initiating event or mitigating its consequences, the evaluation of system importance using F-V importance measures includes both aspects contributing to the risk of an accident. Figure F.2-3 shows the relative risk importance of systems at Braidwood Unit 1 from both initiating event causes and mitigation aspects, based on CDF. The Unit 2 results are very similar; the differences between the units have minor impacts on CDF. Note that basic events representing initiating event pipe rupture (LOCAs and internal floods) and operator actions are not included on the system importance figure since they do not directly relate to system component performance.

As seen in Figure F.2-3, the Essential Service Water (SX) system is the most important system with about 38% contribution. Much of the SX system importance is due to its role as an initiator. Very few options are available to prevent core damage after a total loss of SX.

The Auxiliary Electric Power (AP) system contributes to 14% of core damage frequency. This contribution reflects both initiating events that can lead to Loss of SX or Loss of CC as well as AP component failures.

The Component Cooling Water (CC) system is next most important at 10%. It also gets much of its importance due to its role as an initiating event.

The Auxiliary Feedwater (AF) system is the next most risk important system (4%) at Braidwood from a CDF perspective. The contribution from AF includes loss of the manual crosstie capability that was installed to allow the motor driven AF pumps to be used for either unit. This effectively decreased the available AF pumps per unit from 3 pumps to 2 pumps.

A similar effect results in normal Feedwater (FW) showing as next most important at 3%. This contribution includes both loss of feedwater as the initiating transient and loss of the pumps as a potential source of feedwater to the steam generators.

F.2.2.4 IMPORTANT OPERATOR ACTIONS

During the course of an accident, significant benefit is gained from the correct performance of the operator crew in implementing the appropriate Emergency Operator Procedures as well as performing other actions to place the plant in a safe stable condition. Table F.2-3 lists actions that are significant contributors to CDF.

F.2.3 LEVEL 2 MODEL OVERVIEW

The Braidwood Level 2 model is a state-of-the-art Level 2 analysis structure designed to address the Category II requirements of Regulatory Guide 1.200 and the ASME PRA Standard.

The Level 2 analysis uses available technical work from the Braidwood Level 1 PRA and the Modular Accident Analysis Program (MAAP) results where appropriate, but applies the most recent accident progression research, current industry practices, and realistic plant-specific analyses. The Level 2 model is implemented in the CAFTA software package, which is consistent with the Level 1 PRA.

The Level 2 model is generally consistent with the "Simplified Level 2 Modeling Guidelines," WCAP-16341-P (WEST 2005), which many plants are currently using as a basis for updated Level 2 analyses. This WCAP provides a common, standardized method for PWRs with large dry containments to produce an analysis that generally meets capability category II of the ASME PRA standard. The guidance particularly addresses the latest understanding for induced steam generator tube ruptures, direct containment heating, and other important Level 2 phenomena. While the WCAP is focused on modeling the large early release frequency (LERF) for the ASME standard, it includes guidance for including intact, small, and late releases to provide a more complete, though still standardized, Level 2 analysis. In addition to providing results at this level of detail, the Braidwood Level 2 model is structured to quantify contributions on a "detailed release category" level, which allows the assignment of source terms that are more representative of the sequences to which they are applied.

F.2.3.1 LEVEL 1 TO LEVEL 2 MAPPING

Plant damage states (PDS) and their representative Level 1 accident scenarios provide an interface between the Level 1 and Level 2 analyses. Each Level 1 accident sequence that leads to core damage consists of a unique combination of an initiating event followed by the success or failure of various plant systems (including operator actions). Due to the large number of accident sequences created by the Level 1 PRA, the Level 1 sequences that result in core damage can be grouped into plant damage state bins. Each bin collects all of those sequences for which the progression of core damage, the release of fission products from the fuel, the status of the containment and its safeguards systems, and the potential for mitigating the potential radiological source terms are similar. The detailed containment event tree (CET) then analyzes each plant damage state bin as a group.

Plant damage state bins can be used as the entry states to the containment event tree quantification (similar to initiating events for the Level 1 PRA), or can be used to direct sequences onto specific containment event tree branches. The PDS bins for Braidwood are characterized by the status of containment bypass due to SGTR or ISLOCA, reactor coolant system pressure, and the availability of FW/AFW. A sequence by sequence classification was performed and documented as part of the Level 2 analysis.

F.2.3.1.1 Selection of Plant Damage State Parameters

The definition of plant damage states incorporates information from the outcome of the Level 1 analysis that is important to the determination of containment response and the release of radioactive materials into the environment.

The modeling approach for the current revision of the Level 2 PRA uses the CAFTA software package, which analyzes the Level 1 and Level 2 logic together in a single large fault tree. Active systems such as containment coolers and containment spray (CS) are modeled in the Level 2 analysis alongside the Level 2 phenomenological events in order to accurately account for system dependencies with Level 1 systems, such as actuation signals, electrical power, and cooling water.

Along with containment systems performance, the CETs consider the influence that physical and chemical processes have on the integrity of the containment and on the release of fission products once core damage has occurred. The important physical conditions in the RCS and the containment include the pressure inside the reactor vessel at the onset of core damage, whether the reactor cavity is flooded, and the availability of cooling on the secondary side of the steam generators.

In the Level 2 analysis, the RCS pressure identified in the definition of PDSs is that which occurs at the onset of core damage. Events that could influence the change in pressure after the onset of core damage but prior to vessel breach are addressed in the CET. The two most important effects of high pressure for a Level 2 PRA are challenges to the steam generator tubes and direct containment heating. Because of this, two RCS pressure level categories are considered in the PRA: high and low. Pressure level assignment was based on the accident initiators (e.g., medium and large LOCAs result in low pressure) and the availability of feedwater (which results in pressure low enough to alleviate steam generator tube challenges). In general, either a medium/large LOCA, depressurization through the PORVs, or makeup to the steam generators is required to reach low pressure. Without secondary side cooling, smaller LOCAs (including seal LOCAs) and transients are modeled as high pressure scenarios.

AFW/FW availability is tracked separately from RCS pressure in the plant damage states because it is used in the scrubbing assessment for SGTR scenarios and because it impacts the timing of low pressure core damage scenarios.

Initiating events that bypass containment are treated separately in the Level 2 CET. As mentioned in the discussion of top events, containment bypass is identified by ISLOCA and SGTR events.

F.2.3.1.1 Plant Damage State Classifications

The plant damage state, therefore, is a three character code that defines the important sequence characteristics for the Level 2 analysis (containment status, RCS pressure, AFW Availability). The assignment of each individual Level 1 sequence is based on the following scheme:

- Containment Bypassed (by initiator, not containment isolation failure)
  - B: Bypass (ISLOCA or SGTR)
  - N: Not bypassed (all other events)
- RCS Pressure
  - H: High Pressure (sequences without significant RCS leakage, anticipated transient without scram (ATWS) sequences)
  - L: Low Pressure (sequences that depressurize due to significant RCS leakage, such as Large LOCA or Medium LOCA).
  - -: Not Used (e.g., for containment bypass scenarios, RCS pressure is not asked)
- AFW/FW Available
  - A: AFW or FW is available to provide makeup to the SGs (AFW is assumed to be available for pass through nodes. The exception is for secondary line break cases where AFW operability may be compromised).
  - N: AFW/FW is not available to provide makeup to the SGs.
  - -: Not Used (e.g., for containment isolation failure scenarios, AFW/FW availability is not asked)

Table F.2-4 provides the mapping of the Level 1 sequences to the Braidwood plant damage states. Table F.2-5 documents the correlation between the Plant Damage States and the Level 2 sequences (i.e., defines which PDSs are used as “initiators” for the Level 2 sequence).

F.2.3.2 CONTAINMENT EVENT TREE DESCRIPTION

To assess the accident progression following a core damage event, this Level 2 analysis uses the containment event tree shown in Figure F.2-4 based on the containment event trees (CETs) provided in WCAP-16341-P. While the function of the CET is essentially the same as the WCAP CETs, some changes were made to accommodate the capabilities and features of Braidwood PRA model. The event tree begins with one or more core damage sequences, and then asks a number of questions to determine the type of release, if any, that occurs. Each question is modeled as a top event in the event tree and the outcome is based on previous work for Braidwood (including logic taken from the existing model), recent accident progression research, and the guidance provided in the WCAP. Each top event in the event tree is discussed below.

Plant Damage States

This first node of the containment event tree represents the collection of all core damage sequences from the Level 1 PRA into plant damage states. The assignment of core damage sequences to plant damage states provided in Table F.2-4.

Containment Bypass

Level 1 PRA sequences with an initiating steam generator tube rupture or an unisolated interfacing systems LOCA (ISLOCA) will bypass containment and are addressed by this node. In the CET, the “down” branch on this node represents the bypassed condition while the “up” branch is used for non-bypassed scenarios.

The Braidwood-specific ISLOCA analysis does not explicitly show that the likely release paths from ISLOCAs would be submerged and no credit is taken for scrubbing by any potentially overlying pool of water. In addition, no credit is assumed to be available for scrubbing by the auxiliary building.

For SGTR core damage scenarios, the analysis assumes that the steam generator PORV will stick open once it passes water, providing a direct path to the atmosphere. While slightly conservative, this assumption is made because the SG PORVs are not designed to pass high pressure water and assuming the PORV sticks open simplifies the analysis. For steam generator tube rupture cases with AFW available, the “Scrub” node accounts for the potential of the operators to maintain water over the tubes to provide release scrubbing.

Containment Isolation

For non-bypass scenarios, the possibility of containment isolation failure exists to provide a fission product release path through containment. The existing Braidwood PRA provides the associated containment isolation system (CIS) fault trees. The Level 2 model directly incorporates the CIS fault tree model into this top event. The containment isolation system includes all potential penetration locations with pipe sizes greater than 2 inches. Further details of the containment isolation system analysis are located in the Containment Isolation System Notebook.

Reactor Coolant System Pressure

The next two top events are both used to characterize whether RCS pressure has been reduced enough to preclude induced SGTR events, but this node also considers if the degree of depressurization is large enough to preclude high pressure melt ejection events related to early containment failure (below about 200 psig based on WCAP 16341-P). A success (up path) on the RCS Pressure node represents core damage scenarios where the reactor coolant system is at low pressure due to a medium or large loss of coolant accident (identified by the plant damage state). Low pressure means that pressure is insufficient to challenge the steam generator tubes or result in direct containment heating later in the accident progression. The branch is determined by the initiating event from the Level 1 PRA.

AFW or FW Available

Another method for reducing reactor pressure is through use of the steam generators. If steam generator makeup is available to the SGs as dictated by the Level 1 model logic, a decay heat removal path is available and the reactor can be reduced in pressure (to around 1000 psi). This pressure reduction will eliminate the challenge to the steam generator tubes, but it is not assumed to preclude the potential for direct containment heating (which is negligible for Braidwood). In general, AFW/FW is considered available for heat removal if flow is available to 3 of 4 SGs or to 2 of 4 SGs in conjunction with operator action to manage the cooldown process. The Level 1 PRA is used to identify the availability of Feedwater and AFW, which is traced in the Level 2 PRA through the assignment of plant damage states.

Water Over SG Tubes

For SGTR events, the magnitude of the release would be reduced if the radionuclides have to travel through a pool of water. This node is used for SGTR scenarios with AFW available and represents the probability that the operators will maintain about 10 feet (or more) of water over the top of the SG tubes (release scrubbing). Based on the guidance in WCAP-16341-P, the magnitude of the release can be reduced from Large to Small if the SG water level is maintained at least 10 feet above the top of the SG tubes. For Braidwood, a plant specific human reliability analysis (HRA) was performed to develop a probability of failing to perform this control task. The plant procedures instruct the operators to control level between 40% and 50% narrow range, which corresponds to between 7 and 8.8 feet above the top of the SG tubes. The procedure bases indicate this action is directed for the purpose of providing a scrubbing mechanism for any releases through the tubes and while the depth of water is less than the 10 feet described in the WCAP, it is considered to be adequate. The plant specific MAAP results demonstrate the large reduction in the source term resulting from a water depth of about 7 feet. The “up” path in the CET represents the condition in which water level is successfully maintained above the SG tubes.

No Pressure-Induced Steam Generator Tube Rupture

Core damage sequences that continue on the high pressure branch are assumed to be at or near the primary PORV/safety relief valve setpoint. Without water in the steam generators, there is a possibility of pressure-induced steam generator tube rupture early in the scenario. Because the pressure is high from the beginning of the scenario, this question is asked prior to any operator actions or other reactor coolant system failures that could depressurize the RCS. Details of this evaluation are based on WCAP-16341-P and are documented in the Braidwood Level 2 document. This event is modeled via basic event 1L2-SGT-VF-PISGR. The "up" path in the CET represents the condition in which no pressure induced steam generator tube rupture (PI-SGTR) occurs.

RCS Depressurization

If the steam generator tubes survive the initial pressure differential, the operators could take action to depressurize the reactor coolant system in order to reduce the likelihood of tube rupture or direct containment heating. To do so, the operators would open a primary system PORV. If successful, the scenario transfers to a low-pressure accident progression. If the RCS is not depressurized, either due to human inaction or equipment failure, additional high-pressure failures are considered. This action appears in the plant Severe Accident Control Room Guideline Initial Response (SACRG-1) as well as in the emergency operating procedures (1BWFR-C.1, "response to inadequate core cooling"). This top event is modeled by gate 1HIGH-P and the HRA for the action is documented in the Braidwood Level 2 document, which includes consideration of human dependence factors. The gate couples the existing system fault tree with an operator action 1RY-DEPL2--HPVOA, "OPS FAIL TO DEP RCS AFTER CD TO PREVENT INDUCED TUBE RUPTURE". The human error probability for this operator action is set to 2.5E-02 based on the HRA performed to support the Braidwood Level 2 analysis. The "up" path in the CET represents the condition in which depressurization is successful.

No Thermally-Induced Steam Generator Tube Rupture

With the reactor coolant system remaining at high pressure and without feedwater to enough steam generators to depressurize the reactor, the likelihood of thermally-induced creep rupture of steam generator tubes is addressed. As with pressure-induced tube rupture, the age and condition of the steam generator tubes must be considered. Failure probabilities for moderately-damaged tubes are used to account for plant aging during the license renewal term. Details of this evaluation are in the Braidwood Level 2 document. Basic event 1L2-SGT-VF-

TISGR represents the probability in the model. The “up” path in the CET represents the condition in which no thermally induced steam generator tube rupture (TI-SGTR) occurs.

Hot Leg Rupture

During high-pressure core damage scenarios, a "race" occurs to determine where the RCS will first fail. While the reactor vessel will eventually fail as the molten core degrades the lower vessel head, failures may also occur in the steam generator tubes (discussed above) or in the hot leg or surge line of the reactor coolant system. For high-pressure, station-blackout-like scenarios which tend to occur on this branch, the likelihood of hot leg failure is very high. Based on the WCAP, this analysis uses a likelihood of 98% for hot leg failure (basic event 1L2-RCS-VF-DEP2 is used to represent the probability of vessel failure (0.02)). When hot leg failure occurs prior to vessel breach, the reactor coolant system depressurizes prior to failing the lower vessel head, thus eliminating the possibility of high-pressure core melt events leading to direct containment heating. This is generally a beneficial failure since it prevents direct containment heating. The “up” path in the CET represents the condition in which hot leg failure occurs before vessel breach.

For scenarios in which Hot Leg Rupture is asked after a thermally induced tube rupture, recent State of the Art Consequence Analyses (SOARCA) insights indicate that it is likely that the hot leg will fail at about the same time as the TI-SGTR event. If the hot leg fails shortly after the TI-SGTR, then the release pathway is essentially terminated. The radionuclides from the core are transferred into containment rather than to the secondary side through the broken SG tubes. Event 1L2-NO-HLF-TISGTR (0.1) represents the probability that a hot leg failure does not occur at or shortly after the TI-SGTR such that the release continues through the broken SG tubes. The event probability is based on NUREG/CR-7110 (NRC 2012) in which multiple sensitivity analyses indicate that the hot leg would fail within 10 minutes after TI-SGTR and that only 0.6% of the iodine inventory would be released by the time of the hot leg failure. Based on the rapid increase in the creep rupture damage index at the time of TI-SGTR, it would be unlikely that the hot leg would remain intact for a period long enough for the release to transition to a point where it may be considered “large” (potentially 10% of the Iodine/Cesium based on WCAP-16341-P). In this case, the 0.1 probability of the hot leg remaining intact was assigned based on judgment to enumerate an “unlikely” event (“down” branch in the CET). The “up” path in the CET represents the condition in which hot leg failure occurs at about the time of TI-SGTR to terminate the release through the tubes.

<u>Containment Failure at Vessel Breach</u>

Three primary causes for containment failure at the time of reactor vessel breach apply to Braidwood – steam explosion, hydrogen burn, and direct containment heating. The analysis of these containment challenges follows the guidance in WCAP-16341-P. Low pressure sequences (such as due to a LOCA) reduce reactor coolant system pressure to the point where containment is only subject to steam explosion and hydrogen burn challenges. Low pressure sequences due to steam generator cooling do not depressurize as far, and therefore consider steam explosion, hydrogen burn, and direct containment heating. High pressure sequences with depressurization after core damage due to operator action or hotleg failure are primarily subject to hydrogen burn challenges. High pressure scenarios at the time of vessel breach are primarily subject to direct containment heating challenges. Therefore, different branches through the event tree require different early containment failure probabilities. This model assigns probability CFE1 to the combination of steam explosion and hydrogen burn, CFE2 to hydrogen burn by itself, CFE3 to direct containment heating, CFE4 to the combination of all three effects. Recent research has provided an improved understanding of these phenomena and each is discussed below.

Ex-vessel steam explosions due to the pouring of the molten core into a pool of water can challenge the integrity of the containment via damage to the reactor cavity. Based on WCAP-16341-P, this is a greater issue for free-standing reactor cavities (as opposed to excavated cavities). Because Braidwood is an excavated cavity, steam explosions do not pose a failure mechanism for early containment failure.

Hydrogen burns can challenge the integrity of the containment by creating high pressure excursions. The amount of hydrogen released into containment depends upon the amount of core damage at the time of vessel failure. Scenarios that lead to hydrogen burns at plants like Braidwood are limited to about 50% zirconium oxidation (excluding in-vessel recovery cases). Based on WCAP-16341-P, the plant-specific probability of early containment failure at Braidwood due to hydrogen burn is less than 0.001 at 40% oxidation and at 50% oxidation. To capture the possibility of containment failure due to hydrogen burn and/or steam explosion and maintain flexibility in the model, a probability of 0.001 will be used for both CFE1 and CFE2 in the model.

Direct containment heating (DCH) is also addressed by WCAP-16341-P. The WCAP reports plant-specific conditional containment failure probabilities due to direct containment heating for several plants, including Braidwood. The suggested probability is reported as 0.000 to cover all scenarios, and includes the effects of blowdown of the RCS, debris-to-gas heat transfer, exothermic metal/steam & metal/oxygen reactions, and hydrogen combustion that occur during a high-pressure melt ejection. To capture the possibility of DCH and maintain flexibility in the model, a CFE3 probability of 0.001 will be used in the model.

Note that previous Braidwood containment analyses have identified that the Unit 2 containment failure probabilities are slightly higher than the Unit 1 containment failure probabilities due to the existence of Bunker Ramo electrical penetrations in each Unit 2 containment. The containment failure probabilities due to DCH reported in the WCAP are copied from NUREG/CR-6338 (NRC 1996), which recognizes this difference between the Braidwood units (See Table 6.1 and Appendix D of NUREG/CR-6338). However, the strength of the unit 2 containments is sufficient to produce the same 0.000 failure probability for DCH, thereby removing the Unit 1/Unit 2 difference from the new Braidwood Level 2 model.

Based on the above assessments, the probability of early containment failure at Braidwood is negligible for any sequence. However, in order to maintain flexibility in the model for sensitivity analyses, all four early containment failure probabilities (CFE1, CFE2, CFE3, & CFE4) are maintained in the model and assigned a probability of 0.001.

Reactor Containment Fan Coolers

Containment Heat Removal in the Braidwood Level 2 model can be accomplished only through the Reactor Containment Fan Coolers (RCFCs). The Containment Spray system, which is described separately, has no heat removal capability and RHR is not included given that core damage would generally have been avoided if it had been available. The Level 2 PRA models the containment heat removal function via gate 1CHR in the general event tree based on the WCAP, which is linked to the RCFC logic previously developed for the Braidwood model. One of the four RCFCs is required for success.

Note that for some Level 2 scenarios, this function may not be available due to power or cooling water failures; however, the fault tree models these support systems accordingly. Failure of containment heat removal will allow the containment to slowly pressurize until failure. The plant-specific MAAP calculations use a median failure pressure of 125 psig to define containment overpressure failure for Unit 1 (containment shell failure) and 98 psig for Unit 2 (Bunker Ramo Electrical Penetrations).

Containment Spray

The Containment Spray (CS) system at Braidwood is not connected to a heat sink, cannot provide containment heat removal alone, and is considered separately in the CET for its ability to transfer water to the reactor cavity. The Braidwood Level 1 PRA does not include the containment spray system and the system model was developed to support the Level 2 analysis.

When containment heat removal is available to prevent long term containment overpressurization failures, consideration is given to the potential for basemat meltthrough. The basemat meltthrough probability in WCAP-16341-P is dependent on multiple variables, including whether or not there is water on the containment floor (i.e., in the reactor cavity). The simplifying assumption made in the WCAP Level 2 model related to the presence of water in the reactor cavity is that, if containment spray functions, the volume of the RWST is transferred to the cavity; otherwise, the cavity is assumed to be “dry”.

For cases in which containment heat removal fails, success of containment spray could reduce the magnitude of the release by providing a scrubbing mechanism within containment. For the Level 2 analysis, no credit is taken for the impact of scrubbing to reduce the magnitude of the late release. This is primarily because for the dominant scenarios, the containment spray pumps would be unavailable (loss of Service Water Events fail the Containment Spray pumps).

Basemat Meltthrough

If no other containment failures occur during an accident scenario and containment heat removal exists, the last containment failure mode to examine is basemat meltthrough. If not cooled by an overlying water pool, the molten corium will begin to attack and erode the concrete basemat. Several beneficial factors at Braidwood make basemat meltthrough less severe than other plants. First, Braidwood has a "wet" containment design. If the RWST is injected into the primary system or containment via ECCS or containment spray, the water will drain to the reactor cavity and provide cooling of the molten corium, thus reducing the chance of basemat meltthrough. Second, the Braidwood basemat is 9 feet thick under the reactor. Even without cooling of the molten corium, basemat meltthrough will require many hours to erode through this thickness of concrete. Third, Braidwood has a relatively large cavity floor area, meaning the molten corium will have more space to spread. This results in a shallow layer (about 8 inches thick) of corium which can be more easily cooled by overlying water (over 30 feet). For the containment event trees, sequences including injection of the RWST can avoid basemat meltthrough with a high probability of success, while sequences without injection are subject to eventual basemat meltthrough. Basemat meltthrough is only questioned if containment heat removal is successful and the status of the cavity (wet vs. dry) is determined based on the operation of the Containment Spray (CS) system. The probability of having basemat meltthrough with a shallow layer of corium and a deep water pool in the cavity is assigned a value of 0.05 (basic event 1L2-CNT-VF-BMMTW), based on guidance in the WCAP. For scenarios where the cavity is dry, basic event 1L2-CNT-VF-BMMTD models eventual basemat meltthrough with a probability of 1.0.

F.2.3.3 LEVEL 2 RELEASE CATEGORY DEFINITIONS

The Level 2 PRA containment event tree sequences are categorized into four general release categories, which are described below.

INTACT

Containment structure and function succeed and prevent a substantial release of fission products. Source term calculations assume normal plant leakage to determine offsite consequences.

LATE

Containment failure occurs, but is considered late because of a significant time delay between core damage and containment failure. Releases may be large or small, but offsite consequences are limited to latent health effects and contamination.

SERF

Containment function is bypassed, but the radioactive release is scrubbed by an overlying water pool or limited by the size of the containment failure, reducing the offsite health effects.

LERF

WCAP-16341-P identifies the types of sequences that should be defined as Large-Early evolutions based on a review of documented industry definitions for “Large” and “Early”. Braidwood uses the same classification scheme to identify the Large-Early sequences in the CET. In general, containment failure occurs early in the scenario. Early releases are defined as those releases that occur within a short time following core damage based on plant-specific source term calculations, such that adequate evacuation time is not available to protect the public from prompt health effects. “Large” releases are determined by plant-specific source term calculations for the sequences defined to be “Large-Early” (i.e., “Large” is not tied to a specific fraction of inventory for a given radionuclide), but it is generally greater than 4 percent of the CsI inventory for Braidwood.

F.2.3.3.1 Detailed Level 2 Release Category Definitions

A number of different Level 2 sequences contribute to each of the four general release categories above. Because the actual release characteristics will vary depending on how the containment event tree progresses, detailed release categories further define the Level 2 sequences. These detailed release categories consider the scenario characteristics and the ultimate containment failure mode. Each Level 2 sequence is mapped into one of these detailed release categories.

INTACT

This release category captures all of the INTACT sequences. Because the containment is essentially intact, sequence variations have a negligible impact on the release characteristics. INTACT-01, INTACT-02, INTACT-03, INTACT-04, and INTACT-05 contribute to this category. Releases to the environment are via normal containment leakage.

LATE-BMT-AFW

This release category captures sequences that result in basemat meltthrough with feedwater available to the steam generators. Because basemat meltthrough takes a significant amount of time to erode the thick basemat at Braidwood, the release is small and significantly delayed. LATE-01, LATE-02, LATE-04, and LATE-05.

LATE-BMT-NOAFW

This release category captures sequences that result in basemat meltthrough without feedwater available to the steam generators. Because basemat meltthrough takes a significant amount of time to erode the thick basemat at Braidwood, the release is small and significantly delayed. LATE-07, LATE-08, LATE-10, and LATE-11 contribute to this category.

LATE-CHR-AFW

This release category captures sequences that result in containment failure due to late overpressure with feedwater available to the steam generators. LATE-03 and LATE-06 contribute to this category.

LATE-CHR-NOAFW

This release category captures sequences that result in containment failure due to late overpressure without feedwater available to the steam generators. LATE-09, LATE-12, LATE-13, and LATE-14 contribute to this category.

LERF-ISLOCA

This release category captures sequences caused by an unisolated ISLOCA. Those sequences from LERF-11 with ISLOCA initiating events contribute to this category.

LERF-CI

This release category captures sequences that result in containment isolation failure. LERF-09 contributes to this release category.

LERF-CFE

This release category captures sequences that result in early containment failure due to steam explosion, hydrogen burn, and/or direct containment heating at the time of vessel breach. LERF-01, LERF-02, LERF-03, LERF-04, LERF-05, AND LERF-06 contribute to this category.

LERF-SGTR-AFW

This release category captures sequences caused by a steam generator tube rupture that have successful operation of auxiliary feedwater, but the operators fail to control SG level above 40% narrow range level and the water inventory in the steam generators does not provide significant fission product scrubbing. With or without isolation of the ruptured steam generator, SGTR sequences with core damage provide a direct release path to the environment through the steam generator relief valves. Those sequences from LERF-10 with SGTR initiating events and successful AFW contribute to this category.

LERF-SGTR-NOAFW

This release category captures sequences caused by a steam generator tube rupture that also have failed AFW. With or without isolation of the ruptured steam generator, SGTR sequences with core damage provide a direct release path to the environment through the steam generator relief valves. Those sequences from LERF-11 with SGTR initiating events and AFW failure contribute to this category.

LERF-ISGTR

This release category captures sequences that result in either a pressure-induced or thermally-induced steam generator tube rupture that bypasses containment. LERF-07 and LERF-08 contribute to this category.

SERF -TISGTR-HLF

The sequences within this path are those that evolve into thermally induced steam generator tube ruptures, but are shortly followed by a hot leg failure, which effectively terminates the release from the ruptured steam generator. Basemat failure may or may not occur; however, the leakage from the ruptured SG tubes before hot leg failure results in a small/early release and this release is the dominant concern for this sequence. SERF-01 contributes to this category.

SERF-SGTR-AFW-SC

Sequences within this path are bypass scenarios due to a steam generator tube rupture. The operators successfully maintain feedwater in the ruptured steam generator to scrub the radioactive release, resulting in a small, early release through the steam generator tube rupture. SERF-02 contributes to this category.

F.2.3.4 REPRESENTATIVE SEQUENCES

For each detailed release category defined above, accident progression calculations predict the timing and amount of release. Table F.2-6 describes the representative sequences for each detailed release category. The first column includes the dominant Level 2 sequence to each release category, with the percentage of that category that the sequence contributes. The representative sequences are selected considering both the likelihood of the scenario and its potential consequences. The potential consequences of the scenarios are based on judgment given that source terms are generally not available for a sequence unless it is identified as a representative sequence.

Because source terms are applied at the detailed release category level, however, the sequences within any given release category typically have very similar release characteristics. The differences are often limited to whether feed and bleed or recirculation fails and in many cases, such a difference would have a minimal impact on the source term. The sequence that is judged to be associated with a higher potential source term is used as the representative sequence unless there is another sequence that accounts for a majority of the release category frequency and the sequence with the “higher” source term accounts for less than about 10 percent of the release category frequency. In those cases, the “majority” sequence would be chosen as representative.

F.2.3.5 SOURCE TERM RESULTS

The Braidwood MAAP (version 4.06) model was used to calculate source terms for each of the detailed release categories above. The timing of important events and the timing and magnitude of fission product releases for each representative sequence is documented in Table F.2-7.

F.2.3.6 LEVEL 2 RELEASE CATEGORY FREQUENCIES

Table F.2-8 shows the calculated results for the detailed release categories.

F.2.4 PRA MODEL TECHNICAL ADEQUACY FOR SAMA

As part of the PRA maintenance program, the Braidwood PRA model has been subjected to both internal and peer reviews since the submittal of the IPE, including the following:

- 1999 Westinghouse Owner’s Group Peer Review (performed on Revision 0 of the PRA)
- Standard Self Assessments – Several self-assessments have been performed on the PRA, the most recent of which was completed in June, 2012.
    - Performed on model of record BB011a,
    - Evaluated against ASME/ANS RA-Sa-2009 (ASME 2009)

The 1999 Westinghouse Owners’ Group peer review resulted in a total of 27 Level “A” and “B” Findings and Observations, all of which have been closed out.

The 2012 self-assessment identified two (2) supporting requirements (SRs) that were classified as not being met and about twenty (20) that were considered to only meet the Capability Category I requirements.

The following table summarizes the issues related to the SRs that were “not met” and how this assessment could potentially impact the SAMA analysis. Note that the review was performed on the BB011a “LERF only” model that was replaced by the Braidwood 2012 Level 2 model (BB011b1) used to support the SAMA analysis.

Review of ASME Supporting Requirements Classified as Not Met in the BB011a Self-Assessment

SR	Assessment Comments	Potential Impact on SAMA
LE-G5	Since the NUREG/CR-6595 approach has been used, the LERF analysis is inherently structured to support applications that do not require significant capability for distinction among application-related changes to LERF contributors. LE-G5-01 and URE BB-0966	This SR is related to identifying and documenting potential limitations in the LERF analysis that would impact applications. This is a documentation issue and would not directly impact the SAMA analysis. In addition, the 2012 Level 2 model used to support the SAMA analysis includes an assessment of model limitations and this SR is met.
LE-G6	BB-PRA-015 does not include a definition of significant accident progression sequence. Since the LERF methodology follows the conservative NUREG/CR-6595 process, not meeting this requirement has no significant impact on risk-informed applications for which Capability Category I LERF is appropriate. LE-G6-01 and URE BB-0967	The Braidwood Level 2 model used to support the SAMA analysis includes a definition of a significant accident sequence and it is consistent with the definition provided in the ASME/ANS RA-Sa-2009. This issue has been resolved.

The table below includes the original assessment comments associated with the SRs that only met Capability Category I in conjunction with an assessment of how the failure to meet Capability Category II could impact the SAMA analysis. Most of the SRs that were classified as only meeting the Capability Category I requirements were related to the BB011a "LERF only" model that was replaced by the Braidwood 2012 Level 2 model (BB011b1) used to support the SAMA analysis.

Review of ASME Supporting Requirements Classified as Capability Category I in the BB011a Self-Assessment

SR	Assessment Comments	Potential Impact on SAMA
IE-A8	B/B PRA-001, Rev. 5, Initiating Event Analysis, does not include a plant personnel interview section or discussion. This gap is captured in F&O IE-A8-001 and URE BB-0958.	Capability Category II requires plant personnel interviews as part of the initiating event identification process. The existing list of initiating events is believed to be complete and while it is possible other events could exist, they would be small contributors and would not impact the SAMA analysis. No meaningful impact on SAMA.
SC-A5	The mission time as used in the PRA analysis is 24 hours. Refer to section 2.1.2 and Table 2-1 of BB PRA-003, revision 2, Success Criteria Notebook. SC-A5-01 and URE BB-0961	For SR SC-A5, the Byron / Braidwood PRA model uses a 24-hour mission time for most events. Core damage is assumed for scenarios that do not reach core damage in 24 hours, but are not in safe/stable state. Additional work could be performed to support redefining some sequences as non-core damage events. For SAMA, the current modeling approach is conservative in that it increases the maximum averted cost risk (MACR) and adds potential sequences that could be recovered by a SAMA (increasing the averted cost benefit of a SAMA). Due to human dependence issues and limits on the ways recovery actions are credited in the PRA, the potential changes to mission time assessments to support alternate endstate classifications are likely limited. No meaningful impact on SAMA.
HR-E3	While the HRA-related procedures were discussed with Operations and Operations training personnel, only a subset of the entirety of procedure usage within the modeled sequences were covered in operator interviews and simulator observations as documented in Appendices D, E, and F of the HRA Notebook (BB-PRA-004, VOLUME 1). Insights from the interviews and observations are factored into the associated HFE evaluations as documented in Appendices A and F of the HRA Notebook (BB-PRA-004, VOLUME 1). Refer to Section 3 and Appendices A, D, E, and F of the HRA Notebook (BB-PRA-004, VOLUME 1).	The incorporation of operator interview results into HRA can impact the analyst's understanding of the modeled actions. For Braidwood, not all actions in the model or all sequences in which the actions are used in the model were discussed in the interviews. The most important actions are well defined and are supported by interviews. No significant changes to the PRA results would be expected as a result of performing interviews for the remaining actions. No meaningful impact on SAMA

Review of ASME Supporting Requirements Classified as Capability Category I in the BB011a Self-Assessment

SR	Assessment Comments	Potential Impact on SAMA
HR-E4	Only a subset of the entirety of plant response in the modeled scenarios were covered in operator interviews and simulator observations as documented in Appendices D, E, and F of the HRA Notebook (BB-PRA-004, VOLUME 1). Insights from the interviews and observations are factored into the associated HFE evaluations as documented in Appendices A and F of the HRA Notebook (BB-PRA-004, VOLUME 1). Refer to Section 3 and Appendices A, D, E, and F of the HRA Notebook (BB-PRA-004, VOLUME 1).	The incorporation of simulator observation data into HRA can potentially provide more accurate timing information and an enhanced understanding of the modeled actions beyond what interviews alone can provide. For Braidwood, not all actions in the model were observed in the simulator. There is no way to predict what changes, if any, to timing or modeling assumptions would result from additional operator interviews. The availability of interview information for the most important actions at Braidwood limits the potential knowledge gaps that may otherwise be filled by simulator observations. No meaningful impact on SAMA
LE-B1	The NUREG/CR-6595 methodology is used to identify LERF contributors. The set defined is consistent with the contributors in Table 4.5.9-3 for large dry containments. A search for unique plant issues, required for Capability Category II, was not performed. Level 1 scenarios are grouped for analysis in the Level 2 event trees based on the methodology presented in NUREG/CR-6595. Plant damage states are used to maintain the link to the appropriate supporting MAAP runs.	The WCAP methodology was used to identify LERF contributors and this issue is considered to be addressed by the Level 2 model used to support the SAMA analysis. No impact.
LE-C1	The NUREG/CR-6595 methodology is used to assess containment challenges resulting from the various LERF contributors. The LERF fault tree logic models the NUREG/CR-6595 CET logic, and contributions are grouped by LERF event tree designator.	WCAP methodology developed accident sequences consistent with the failure modes identified and the plant specific failure rates provided in that guidance were used in the Braidwood Level 2 model. No impact.
LE-C2	The NUREG/CR-6595 methodology is used to assess containment challenges resulting from the various LERF contributors. Treatment of operator actions is therefore conservative.	The Braidwood severe accident control room guidance was reviewed to identify and incorporate actions that were judged to have the potential to mitigate severe accidents. No impact.

Review of ASME Supporting Requirements Classified as Capability Category I in the BB011a Self-Assessment

SR	Assessment Comments	Potential Impact on SAMA
LE-C3	Repair of equipment is not addressed in the LERF model.	No credit was taken for any actions to repair equipment to mitigate the Level 2 accident sequences. AC power recovery is treated in the Level 1 model and no additional credit was applied for the Level 2 model. This is consistent with the general PRA practice of not modeling actions to repair failed equipment due to the uncertainties related to the causes of equipment failure and the availability of timely repair strategies. This is considered to meet the intent of LE-C3. No impact.
LE-C4	The NUREG/CR-6595 methodology is used to assess containment challenges resulting from the various LERF contributors. The LERF fault tree logic models the NUREG/CR-6595 CET logic, and contributions are grouped by LERF event tree designator.	This issue is addressed by the Level 2 model used to support the SAMA analysis. SG flooding and post core damage RCS depressurization was incorporated into the Level 2 model based on a review of the severe accident control room guidance. In addition, State of the Art Consequence Analyses (SOARCA) insights were used to enhance the SGTR analysis. No impact.
LE-C9	The NUREG/CR-6595 approach has been implemented, and credit for equipment operation or operator actions in adverse environments is not credited.	No operator actions that would be taken in adverse environments or opportunities for continued equipment operation in a harsh environment were identified that would realistically mitigate LERF scenarios. Human actions potentially taken after core damage are credited, but they are not in hazardous environments. SOARCA insights were used to enhance the SGTR analysis, however. The Level 2 model used for the SAMA analysis is considered to meet capability category II for LE-C9. No impact.
LE-C10	LE-C9 is Cat I so this SR is Cat I.	The Braidwood severe accident control room guidance and sequences were reviewed to identify potential mitigating factors as part of the Level 2 model used to support the SAMA analysis. This issue is considered to be resolved. No impact.

Review of ASME Supporting Requirements Classified as Capability Category I in the BB011a Self-Assessment

SR	Assessment Comments	Potential Impact on SAMA
LE-C11	The NUREG/CR-6595 approach is modeled; continued operation of equipment or operator actions affected by containment failure is not credited.	No operator actions that would be taken after containment failure or opportunities for continued equipment operation after containment failure were identified that would realistically mitigate LERF scenarios. Human actions potentially taken after core damage are credited, but they are not in hazardous environments. SOARCA insights were used to enhance the SGTR analysis, however. The Level 2 model used for the SAMA analysis is considered to meet capability category II for LE-C11. No impact.
LE-C12	Cat I since LE-C11 is Cat I.	SOARCA results for induced SGTR are supported by plant specific MAAP runs. The Level 2 model used for the SAMA analysis is considered to meet capability category II for LE-C12. No impact.
LE-C13	The NUREG/CR-6595 approach has been implemented, and no credit is taken for scrubbing of containment bypasses.	SG flooding is credited in the Level 2 model and the impact is modeled by plant specific HRA and MAAP runs. This issue is addressed by the Level 2 model used to support the SAMA analysis. No impact.
LE-D2	The NUREG/CR-6595 approach has been used.	A plant specific analysis was used to identify the weakest point in containment and used to define the failure pressure for the plant specific MAAP analysis, but no location specific impact is modeled. Low potential impact.
LE-D3	The NUREG/CR-6595 approach has been used.	A plant specific analysis was used to identify the weakest point in containment and used to define the failure pressure for the plant specific MAAP analysis, but no location specific impact is modeled. Low potential impact.
LE-D5	Steam generator isolation is modeled in the SGTR fault tree logic. The modeling is generally conservative in that any failure of any line to isolate, regardless of size, is treated as failure of SG isolation.	Plant specific, detailed HRA supports the operator action to isolate the SG and the model includes the hardware required to perform the isolation. Additional enhancements to model temperature/pressure effects on hardware operation are expected to have a small impact on SAMA.

Review of ASME Supporting Requirements Classified as Capability Category I in the BB011a Self-Assessment

SR	Assessment Comments	Potential Impact on SAMA
LE-D6	The NUREG/CR-6596 approach is used. An induced steam generator tube rupture ISGTR probability is assigned for the possibility of induced SGTR for sequences per the NUREG methodology.	The WCAP methodology, in conjunction with plant specific analysis of SG PORV response, is considered to meet capability category II requirements. No impact.
LE-E2	Parameter estimates for accident progression phenomena are selected in accordance with NUREG/CR-6595, and are generally conservative.	Phenomena values are based on plant-specific values and industry calculations that match plant specific features based on guidance in the WCAP. This issue is addressed by the Level 2 model used to support the SAMA analysis. No impact.
LE-E3	The LERF model is based on NUREG/CR-6595. Early containment failures (e.g., failure prior to recirc), bypass sequences (e.g., SGTR, ISLOCA), and isolation failures following core damage are modeled as LERF.	This issue is addressed by the WCAP Level 2 model used to support the SAMA analysis. No impact.
LE-F1	The spreadsheet for BB-PRA-015 includes an assessment of LERF contribution by accident class, which is equivalent to identification of the contributors to LERF. Although an assessment by PDS is not currently provided, the information is available to do so. Since the SR wording for Cat I indicates "e.g., PDS" but the wording for Cat II/III does not include the "e.g.", the Category assignment for this SR is Cat I, even though more than an identification of significant contributors has been performed.	Documentation issue, which is considered to be resolved by the Level 2 document. No impact.

Review of ASME Supporting Requirements Classified as Capability Category I in the BB011a Self-Assessment

SR	Assessment Comments	Potential Impact on SAMA
LE-G3	The spreadsheet for BB-PRA-015 includes an assessment of LERF contribution by accident class, which is equivalent to identification of the contributors to LERF. Although an assessment by PDS is not currently provided, the information is available to do so. Since the SR wording for Cat I indicates "e.g., PDS" but the wording for Cat II/III does not include the "e.g.", the Category assignment for this SR is Cat I, even though more than an identification of significant contributors has been performed. LE-G3-01 and URE BB-0964	Documentation issue, which is considered to be resolved by the Level 2 document. No impact.

The Braidwood PRA model BB011b1 results are suitable for use as a resource in the SAMA identification process. This conclusion is based on:

- The PRA technical capability evaluations that have been performed to demonstrate technical adequacy of the PRA,
- The PRA maintenance and update processes that are in place to ensure that the model reflects the as-built, as operated plant.

Although there are some open items from the self assessment that will not be resolved until future model updates are performed, they have insignificant impact on the conclusions of the SAMA analysis.

F.3 LEVEL 3 RISK ANALYSIS

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

F.3.1 ANALYSIS

The MACCS2 code (NRC 1998), version 1.13.1, was used to perform the Level 3 probabilistic risk assessment (PRA) for Braidwood. The MACCS2 code was developed to support probabilistic risk assessments (NRC 1998) and is the code typically used to calculate off-site population dose and costs in support of a SAMA analysis, as recognized in NEI 05-01 (NEI 2005). The atmospheric transport and dispersion straight-line Gaussian modeling incorporated in MACCS2 has been compared against more complex modeling approaches, such as the three-dimensional ADAPT/LODI code, and shown to be acceptable for the purposes of the MACCS2 code (NRC 2004b).

For the Braidwood MACCS2 analysis, the input parameter values used in NUREG-1150 (NRC 1990a), as detailed in NUREG/CR-4551 (NRC 1990b) and reflected in the MACCS2 "Sample Problem A," (NRC 1998) formed the initial bases. NUREG-1150 is a seminal work in PRA performed by the NRC and the national laboratories that includes a Level 3 PRA for five different reactor sites. It was subjected to extensive peer review and has been accepted by the NRC as a standard reference for MACCS2 inputs for SAMA analyses. Where applicable, these initial values were replaced with site specific values applicable to Braidwood and the surrounding region. Site-specific data included population distribution, some economic parameters such as property value of farm and non-farm land, and meteorological data. Generic economic parameters from the NUREG-1150 study for the costs of evacuation, relocation and decontamination were escalated from the time of their formulation (1986) to more recent (July 2012) costs. Plant-specific release data included release frequencies and the time-dependent distribution of nuclide releases from 13 accident sequences at Braidwood. The behavior of the population during a release (evacuation parameters) was based on plant and site-specific set points (i.e., declaration of a General Emergency) and evacuation time estimates (ET 2003). These data were used in combination with site specific meteorology to calculate risk impacts (exposure and economic) to the surrounding population within 50 miles.

F.3.2 POPULATION

The population surrounding the Braidwood site is estimated for the year 2047, the last year of projected operation for Unit 2 given a 20 year license extension.

The population distribution projection was based on year 2000 census data available via SECPOP2000 (NRC 2003). (Year 2010 census data has not yet been incorporated into the SECPOP code or incorporated into the state projection data used to estimate county growth rates at the time of the Level 3 analysis.) The baseline resident year 2000 population from SECPOP was determined for each of 160 grid elements of a polar coordinate grid consisting of sixteen directions (i.e., N, NNE, NE,…NNW) for each of ten concentric distance rings with outer radii at 1, 2, 3, 4, 5, 10, 20, 30, 40 and 50 miles surrounding the site. Transient population data from the Braidwood Evacuation Time Estimate (ETE) study (ET 2003) for the approximate 10 mile radial area around the site was added to the SECPOP permanent population, consistent with the guidance of NEI 05-01 (NEI 2005), on a grid element basis. In addition to the ETE category of transient population, the ETE categories of seasonal residents and special facilities populations were also included in the initial year 2000 population estimate. To estimate growth rates, Illinois and Indiana county population projection data from applicable state data sources for the year 2030 were used. Table F.3-1 presents the county growth rates for the years 2000 to 2030. Individual growth rates were calculated for each grid element based on the county growth rate and the proportion of land in each grid element associated with the applicable counties. The combined resident and transient data (including seasonal residents and special facilities) were projected from year 2000 to 2030, and then from 2030 to 2047 (using the year 2000 to 2030 growth rate times a 0.57 factor, i.e., 17/30) to calculate the 2047 population distribution. If county growth rate data projected a declining population for 2000 to 2030 for a particular county, zero population growth was assumed for that county. This condition only existed for the county of Newton, Indiana.

The total year 2047 population for the 160 grid elements in the region is estimated at 7,554,998. The distribution of the population is given for the 10-mile radius and the 50-mile radius from Braidwood in Tables F.3-2 and F.3-3, respectively.

F.3.3 ECONOMY

MACCS2 requires certain agricultural and land based economic data (fraction of land devoted to farming, annual farm sales, fraction of farm sales resulting from dairy production, and property value of farm and non-farm land) for each of the 160 grid elements. This data can be generated by SECPOP2000 (NRC 2003), but due to known errors associated with the economic parameter processing portion of the SECPOP2000 code, SECPOP2000 was not utilized to develop the county specific economic values for the Braidwood analysis. Instead, the economic values were developed manually following the SECPOP calculation approach documented in NUREG/CR-6525 (NRC 2003) using data from the 2007 National Census of Agriculture (USDA 2009) and 2007 data (for consistency with the census of agricultural data) from the Bureau of Economic Analysis (BEA 2012) for each of the 21 counties surrounding the plant, to a distance of 50 miles. Economic values were updated to July 2012 using the consumer price index (CPI) from the Bureau of Labor Statistics (BLS 2012). The values used for each of the 160 grid elements were the data from each of the surrounding counties multiplied by the fraction of that county's area that lies within that sector. Region-wide wealth data (i.e., farm wealth and non-farm wealth) were based on county-weighted averages for the region within 50-miles of the site using the same economic data sources. The portion of each county within 50-miles of the site was accounted for in the calculation. County specific land use and related economic parameter values are summarized in Table F.3-4.

In addition, generic economic data that is applied to the region as a whole were revised from the NUREG-1150 based data in order to account for cost escalation since 1986, the year that input was first specified. A factor of 2.09, representing cost escalation from 1986 (CPI index of 109.6) to July 2012 (CPI index of 229.1) was applied to parameter values describing cost of evacuating and relocating people and decontamination activities.

MACCS2 generic economic parameter values utilized in the Braidwood analysis are summarized in Table F.3-5.

F.3.4 FOOD AND AGRICULTURE

Food ingestion is modeled using the new MACCS2 ingestion pathway model COMIDA2, consistent with MACCS2 User's Guide (NRC 1998). The COMIDA2 model utilizes national based food production parameters derived from the annual food consumption of an average individual such that site specific food production values are not utilized. The fraction of population dose due to food ingestion is typically small compared to other population dose sources. For Braidwood, only approximately 1.4% of the total population dose is due to food ingestion.

F.3.5 NUCLIDE RELEASE

The core inventory at the time of the accident is based on a plant specific calculation (Exelon 2008b). The core inventory represents bounding isotopic values (i.e., largest) for 100 effective full power days (EFPD) or 542.9 EFPD (end of cycle) for the core operating at 3586.6 MWt, the current licensed power level. This calculation reflects the current fuel management / burnup approach. Table F.3-6 summarizes the estimated Braidwood core inventory used in the MACCS2 analysis. Exelon has submitted a license amendment request (Exelon 2011) for a Measurement Uncertainty Recapture (MUR) power uprate for Braidwood, of approximately 1.63% (i.e., from 3586.6 MWt to 3645 MWt). This proposed power uprate is included in the MACCS2 basecase analysis by including a core inventory scaling factor of 1.0163. The assumption of no MUR power uprate (i.e., scaling factor of 1.0) is evaluated in the sensitivity analysis.

Braidwood nuclide release categories, as represented using the MAAP computer code, are related to the MACCS2 categories as shown in Table F.3-7. Thirteen radiological release categories were modeled, each segmented into three plumes. Consistent with the guidance of NEI 05-01 (NEI 2005), a plume release height of 30.3 m (99.4 ft) above grade is used representing a release from the mid-height of the containment. Buoyant plume rise is modeled assuming a thermal plume heat content of 10 MW for all releases except intact containment (where zero heat content is assumed). A value of 10 MW bounds typical values in NUREG/CR-4551 (NRC 1990b). Assumptions associated with release height and plume heat content are considered in the sensitivity analyses, presented in Section F.7.3.

For each of the thirteen release categories, a representative MAAP case was chosen based on a review of the Level 2 model cutsets and the dominant types of scenarios that contribute to the release category. Brief descriptions of each release category, dominant Level 2 sequences, and the representative MAAP case are provided in Table F.3-8. Representative MAAP cases were run until a plateau of the CsI and CsOH release fractions were achieved. Experience has shown that CsI is a primary contributor to early dose, and CsOH is a primary contributor to late dose and cleanup costs. In some cases, the MAAP cases were run to times that exceeded the plume release times allowed by MACCS2. In such cases, plumes were moved forward in time in the modeling to meet MACCS2 limitations. These time adjustments are noted in Table F.2-7.

Multiple release duration periods (i.e., plume segments) were defined which represent the time distribution of each category's releases. A summary of the release magnitude and timing for those cases is provided in Table F.2-7.

A dry deposition velocity of 0.01 m/sec is used for the MACCS2 analysis, consistent with NRC recommendation as documented in the MACCS2 Sample Problem A (NRC 1998). The dry deposition velocity is considered in the sensitivity analysis, presented in Section F.7.3.

F.3.6 EVACUATION

Reactor trip for each sequence was taken as time zero relative to the core containment response times. A General Emergency (GE) is declared when plant conditions degrade to the point where it is judged that there is a credible risk to the public. For the Braidwood analysis the time of the GE declaration was estimated based on the Braidwood emergency action levels (Exelon 2012). The declaration times are presented in Table F.2-7. For most release categories the GE time is established as the time of core damage. However, a minimum GE time of 30 minutes is used for release categories with core damage projected to occur in less than 30 minutes. For the LERF-SGTR-NOAFW, the GE is declared earlier than the time of core damage based on the known loss of AFW. For two release categories (i.e., LERF-SGTR-AFW and SERF-SGTR-AFW-SC), the GE times were moved forward in time (i.e., earlier) in association with moving the plume segments release time earlier to meet MACCS2 release delay limitations of a maximum of 96 hours following accident initiation. Because the GE time modeled was moved earlier the same amount as the plume segment release times, this earlier modeling of GE time does not impact evacuation related timing issues. The only impact is that there is less time incorporated in the MACCS2 calculation for natural decay thereby adding a slight conservatism to the modeling.

Ninety five percent of the population within 10 miles of the plant (Emergency Planning Zone, EPZ) is assumed to evacuate and 5 percent is assumed not to evacuate, consistent with the MACCS2 User's Guide (NRC 1998a). These values are conservative relative to the NUREG-1150 study (NRC 1990a), which assumed evacuation of 99.5 percent of the population within the EPZ.

The evacuees are assumed to begin evacuation 115 minutes after a general emergency has been declared at a base evacuation radial speed of 4.2 m/sec. The time to begin evacuation and the base speed are derived from the site specific evacuation study (ET 2003). The evacuation speed is a time-weighted average value accounting for season, time of day, and weather conditions. It is noted that the longest evacuation time presented in the study (i.e., full 10 mile EPZ, summer daytime adverse weather conditions) is 4.75 hours (from the issuance of the advisory to evacuate). The evacuation parameters were considered further in the sensitivity analyses presented in Section F.7.3.

F.3.7 METEOROLOGY

Annual hourly meteorology Braidwood data sets from 2008 through 2010 were processed for use in the MACCS2 analysis. Of the hourly data of interest (10-meter wind speed, 10-meter wind direction, multi-level temperatures used to calculate stability class, and precipitation), less than 5% of the data were missing for each of the three years of data. Traditionally, up to 10% of missing data is considered acceptable. MACCS2 requires complete sequential hourly data for the full year, therefore missing data must be estimated. The percentages of data hours that included estimated data for missing data for years 2008, 2009, and 2010 were 4.2%, 2.5%, and 3.1%, respectively. Data gaps were filled in the following manner (order of priority):

- Wind direction data gaps for the 34-foot (10-meter) sensor were filled by using wind direction data from the 203-foot sensor, if available.
- Data gaps of less than six consecutive hours were filled by interpolation.
- Wind speed data gaps of greater than six consecutive hours were filled using the power law and wind speed data from the 203-foot sensor, if available. This was only required for the 2008 dataset.
- Data gaps of six or more consecutive hours were filled by substitution from the same hour of a nearby day.

The 10-meter wind speed and direction were combined with precipitation and atmospheric stability (derived from the vertical temperature gradient) to create the hourly data file for each year for use by MACCS2.

The 2010 data set was found to result (see Section F.7.3 for discussion of sensitivity analysis) in the largest economic cost risk and dose risk compared to the 2008 and 2009 data sets. Therefore, the 2010 hourly meteorology was selected as the base case.

Atmospheric mixing heights were specified for AM and PM hours for each season of the year. These values ranged from 320 meters to 1600 meters, as documented in the Braidwood UFSAR (Exelon 2010), based on Holzworth data (EPA 1972).

F.3.8 MACCS2 RESULTS

Table F.3-9 shows the mean off-site doses and economic impacts to the region within 50 miles of Braidwood for each of 13 release categories calculated using MACCS2. The mean off-site dose impacts are multiplied by the annual frequency for each release category and then summed to obtain the dose-risk and offsite economic cost-risk (OECR) for each unit.

F.4 BASELINE RISK MONETIZATION

This section explains how Braidwood calculated the monetary value of the status quo (i.e., accident consequences without SAMA implementation). Braidwood also used this analysis to establish the maximum benefit that could be achieved if all on-line Braidwood risk were eliminated, which is referred to as the Maximum Averted Cost-Risk (MACR). Per the site PRA model (designated BB011b1), the Unit 1 internal events CDF of 3.57E-05 (at a truncation of 1E-10/yr) was used for the calculations in the following sections. External risk is addressed in Section F.4.6.2.

F.4.1 OFF-SITE EXPOSURE COST

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

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

Where:

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

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

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

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

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

The Level 3 analysis showed an annual off-site population dose-risk of 113.76 person-rem. The calculated value for C using 20 years and a 3 percent discount rate is approximately 15.04. Therefore, calculating the discounted monetary equivalent of accident dose-risk involves multiplying the dose (person-rem per year) by $2,000 and by the C value (15.04). The calculated off-site exposure cost is $3,421,888.

F.4.2 OFF-SITE ECONOMIC COST RISK

The Level 3 analysis showed an annual off-site economic risk of $809,628. Calculated values for off-site economic costs caused by severe accidents must be discounted to present value as well. This is performed in the same manner as for public health risks and uses the same C value. The resulting value is $12,176,493.

F.4.3 ON-SITE EXPOSURE COST RISK

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

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

Equation 1:

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

Where:

W_{IO}	=	monetary value of accident risk avoided due to immediate doses, after discounting
R	=	monetary equivalent of unit dose ($2,000 per person-rem)
F	=	accident frequency (events per year) (3.57E-05 (internal events CDF)) at an average 1E-10/yr truncation
D_{IO}	=	immediate occupational dose [3,300 person-rem per accident (NRC estimate)]
$_S$	=	subscript denoting status quo (current conditions)
$_A$	=	subscript denoting after implementation of proposed action
r	=	real discount rate (0.03 per year)
t_f	=	years remaining until end of facility life (20 years).

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

$$W_{IO} = R\,(FD_{IO})_S\{[1 - \exp(-rt_f)]/r\}$$
$$= 2{,}000 * 3.57E\text{-}05 * 3{,}300 * \{[1 - \exp(-0.03 * 20)]/0.03\}$$
$$= \$3{,}544$$

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

Equation 2:

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

Where:

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

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

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

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

W_{LTO} = R $(FD_{LTO})_S$ {[1 – exp(-rt$_f$)]/r} {[1 – exp(-rm)]/rm}

= 2,000∗3.57E-05 ∗20,000∗{[1 – exp(-0.03∗20)]/0.03} {[1 –exp(-0.03∗10)]/0.03∗10}

= $18,554

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

W_O = W_{IO} + W_{LTO} = ($3,544+$18,554) = $22,098

F.4.4 ON-SITE CLEANUP AND DECONTAMINATION COST

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

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

Where:

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

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

r = real discount rate (0.03)

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

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

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

Where:

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

r = real discount rate (0.03)

t_f = 20 years (license renewal period)

The resulting net present value of cleanup integrated over the license renewal term, $1.95E+10, must be multiplied by the internal events CDF (3.57E-05) to determine the expected value of cleanup and decontamination costs. The resulting monetary equivalent is $695,792.

F.4.5 REPLACEMENT POWER COST

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

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

Where:

PV_{RP}	=	net present value of replacement power for a single event, ($)
r	=	0.03
t_f	=	20 years (license renewal period)

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

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

Where:

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

After applying a correction factor to account for Braidwood's size relative to the "generic" reactor described in NUREG/BR-0184 (NRC 1997) (i.e., 1197 megawatt electric / 910 megawatt electric), the replacement power costs are determined to be 7.27E+09 ($-year). Multiplying 7,27E+09 ($-year) by the CDF (3.57E-05) results in a replacement power cost of $259,472.

F.4.6 MAXIMUM AVERTED COST-RISK

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

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

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

F.4.6.1 INTERNAL EVENTS MAXIMUM AVERTED COST-RISK

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

Maximum Averted Internal Events Cost-Risk

Off-site exposure cost	$3,421,888
Off-site economic cost	$12,176,493
On-site exposure cost	$22,098
On-site cleanup cost	$695,792
Replacement power cost	$259,472
Total cost (per unit)	$16,575,743

This total represents the per unit monetary equivalent of the risk that could be eliminated if all risk associated with on-line internal event hazards (including internal floods) could be eliminated for Braidwood. The internal events MACR is rounded to next highest thousand ($16,576,000) for SAMA calculations. It should be noted that the Phase II cost benefit calculations account for the difference between the rounded MACR and the actual MACR by adding the difference to the averted cost-risk calculated for each SAMA.

F.4.6.2 EXTERNAL EVENTS MAXIMUM AVERTED COST-RISK

The maximum averted cost-risk for external events must be quantified for the cost benefit calculations; however, this cost-risk must be estimated based on information in the IPEEE (ComEd 1997b) given that complete, current, quantifiable external events models are not available for Braidwood (other than for fire, which is discussed further in section F.5.1.6). Resources have been committed to update the seismic model for the site and a fire model update is in progress, but those models are not developed to the point where they can be used for quantitative or qualitative input to the SAMA analysis. As a result, an alternate method of accounting for the external events contributions must be established.

The method chosen to account for external events contributions in the SAMA analysis is to use a multiplier on the internal events results. In previous SAMA analyses, it has been assumed that the risk posed by external events and internal events is approximately equal. This assumption is not unreasonable unless available analyses indicate that there are external events contributors that present a disproportionate risk to the site. Based on the magnitude of the Braidwood fire CDF relative to the internal events CDF, it was concluded that the development of an external events multiplier was warranted.

The external events multiplier is the ratio of the total CDF (including internal and external) to only the internal events CDF. The lack of detailed analyses makes it difficult to establish a meaningful CDF for the non-fire initiator groups; however, some assumptions can be made about the non-quantified initiator groups that could be used to further develop a total external events CDF.

The Braidwood IPEEE methodology implies that if the plant licensing bases are met, the plant and facilities design meets the 1981 Standard Review Plan (SRP) criteria, and the site walkdown does not reveal any potential vulnerability not already considered in the design basis analysis, then the CDF posed by an initiator is less than the 1.0E-06 per year screening criterion. As described in Section F.5.1.6, these conditions are met for Braidwood and no contributors greater than 1.0E-06 were expected for any of the external events excluding internal fires. Based on this condition, a CDF of 1.0E-06 per year could be assumed for each of the contributors for which no complete quantitative basis exists to obtain a more detailed estimate of the external events CDF.

The latest available fire results are from the 2008 revision of the Braidwood fire model (Exelon 2008a). While an update of that model was in progress at the time the SAMA analysis was performed, the process was in its infancy and no information was available that could have been used to provide qualitative or quantitative input to the SAMA analysis. However, insight into the impact of using the latest fire ignition frequencies on the 2008 Braidwood fire model was available via a sensitivity study that was performed as part of the Byron Unit 1 fire analysis. The sensitivity analysis quantified the impact of using the fire ignition frequencies from EPRI 1016735 (EPRI 2008) in place of the NUREG/CR-6850 (EPRI 2005) data. Use of the EPRI 1016735 data reduced the CDF of the Byron Unit 1 model by a factor of 1.262. Because of the similarity of the Byron and Braidwood models, this reduction factor is considered to be applicable to all Byron and Braidwood units. For the purposes of establishing the Braidwood SAMA External Events multiplier, the largest fire CDF quantified for the site is used as the starting point, which is 7.5E-05/yr (from Unit 2). Applying the 1.262 reduction factor to account for the use of the latest ignition frequencies results in a Unit 2 fire CDF of 5.94E-05/yr.

Assuming a CDF of 1.00E-06/yr for the non-fire external events contributors and using a Unit 2 Fire CDF of 5.94E-05/yr, the external events contributions could be summarized as follows:

Modified IPEEE Contributor Summary

Fire	5.94E-05
Seismic	1.00E-06
High Winds	1.00E-06
Transportation & Nearby Facility Accidents	1.00E-06
External Flooding	1.00E-06
Total EE CDF	**6.34E-05**

The External Events multiplier is the ratio of the total CDF (including internal and external events) to the internal events CDF. Using the total external events of 6.34E-05 from above and the Unit 2 internal events CDF of 3.50E-05 (for consistency with the fire CDF), the External Events multiplier is:

EE Multiplier = (3.50E-05 + 6.34E-05) / 3.50E-05 = 2.8

F.4.6.3 BRAIDWOOD MAXIMUM AVERTED COST-RISK

The total MACR can be obtained by multiplying the internal events cost-risk by the EE multiplier of 2.8:

Single Unit MACR = $16,576,000 * 2.8 = $46,412,800

Alternatively, as stated in Section F.4.6, the MACR can be represented by the internal and external events contributions (based on the relative contribution of the CDF values to the total CDF):

Internal Events	=	$16,576,000
External Events	=	$29,836,800
Single Unit Maximum Averted Cost-Risk	=	$46,412,800

The MACR and implementation costs are considered on a per-unit scale for consistency (unless otherwise noted).

F.5 PHASE 1 SAMA ANALYSIS

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

F.5.1 SAMA IDENTIFICATION

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

- Braidwood PRA results and PRA Group Insights
- Industry Phase 2 SAMAs (review of potentially cost effective Phase 2 SAMAs from selected plants, as documented in section F.5.1.3)
- Braidwood Individual Plant Examination IPE (ComEd 1994)
- Braidwood IPEEE (ComEd 1997b)

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

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

It should be noted that the process used to identify Braidwood SAMA candidates focuses on plant specific characteristics and is intended to address only those issues important to the site. An evaluation of the generic SAMAs in NEI 05-01, as they are written, provides little benefit because in most cases the systems are not exactly the same as those at Braidwood. Without modifying the NEI 05-01 SAMAs to match the systems at Braidwood, many would be screened as “not applicable”. Further, the scopes of the generic SAMAs are not tailored to match the needs of a specific plant such that the generic SAMAs may only address a fraction of the required functions. As a result, evaluation of the entire generic SAMA list would only be useful after each SAMA has been modified to address the plant specific risk profile. The processes used for Braidwood were more efficient than evaluating the entire generic SAMA list as written.

F.5.1.1 LEVEL 1 BRAIDWOOD IMPORTANCE LIST REVIEW

The importance list review was performed to identify the failure scenarios most important to Braidwood risk and to develop methods to mitigate those scenarios. For each event on the importance list, the reasons for the event’s importance are determined through sequence and systems analysis. Strategies to mitigate the relevant failures are developed based on accident sequence review, plant knowledge, and industry insights. For Braidwood, importance lists were developed and reviewed for the internal events model while for the fire model, the top contributing fire zone results were reviewed to identify SAMAs.

The importance list itself was developed from the Braidwood PRA cutsets and is comprised of the model’s basic events sorted according to their risk reduction worth (RRW) values. The events with the largest RRW values in this list are those events that would provide the greatest reduction in the CDF if the failure probability were set to zero. Because a PRA’s importance list can be extensive, it is desirable to limit the review to only those contributors that could yield potentially cost beneficial results. One method that can be used to limit the scope of the importance list review is to correlate the RRW value threshold to the lowest expected cost of implementation for a SAMA. Usually, operator action modifications in the form of procedure changes are among the least expensive enhancements that can be made at a site, so they are often used as the representative “lowest cost SAMA”. For Braidwood, operator actions were considered as potential SAMA candidates and documented in Tables F.5-1, F.5-2a, and F.5-2b. The cost of a procedure change varies depending on the type of procedure that is being changed, the scope of the changes that are proposed, and the training program changes, but the lower end of the cost estimates range from $50,000 to $100,000 (CPL 2006). For Braidwood, the upper end of this range ($100,000) is used as the lowest cost SAMA to account for engineering analysis, the update of procedure text and supporting documentation, and training. The cost is considered to be a per unit cost.

The RRW value corresponding to $100,000 was determined to be about 1.006 for the internal events model. In some SAMAs, the RRW correlation is based on the total MACR that accounts for all external events contributions. For Braidwood, this was not done because 1) the fire results were reviewed separately for the purposes of SAMA identification, 2) the fire model is in an interim state. If the surrogate CDF values identified in Section F.4.6.2 for the non-fire external events are considered, the review threshold would be lowered slightly, but the impending implementation of the AFW Cross-tie would conversely increase the threshold slightly. Based on these factors, the use of the current internal events CDF to establish the review threshold is considered to result in an adequate review of the risk contributors for Braidwood.

Based on the RRW correlation to the $100,000 procedure change, the RRW review threshold could be set to 1.006, but because an earlier revision of the importance review was performed to an RRW level of 1.005 and the results were available, they have been included as part of this analysis. Table F.5-1 documents the disposition of each basic event in the Level 1 internal events model with an RRW value of 1.005 or greater. The depth of the RRW review is consistent with NEI 05-01 guidance as well as other SAMA analyses.

For the fire analysis, the review threshold was correlated to the IPEEE screening threshold of a 1.0E-06 CDF. A direct correlation of fire CDF to potential averted cost-risk could be performed, but given the interim state of the model, this was not considered to be the best approach. The fire results are likely overly conservative and are also likely to change as the model is refined, but a review of all contributors with CDFs above 1.0E-06 is considered to provide some assurance the important issues have been identified for the site. Because the units are different with regard to fire events, the review was performed separately for Units 1 and 2. Section F.5.1.6.1 includes the detailed results of the fire zone review.

F.5.1.2 LEVEL 2 BRAIDWOOD IMPORTANCE LIST REVIEW

A similar review was performed on the importance listings from the Level 2 results. In this case, two separate Level 2 importance lists were developed. The reviews were performed on composite importance files for the following release categories:

- Large Early (LERF-ISLOCA, LERF-CI, LERF-CFE, LERF-SGTR-AFW, LERF-SGTR-NOAFW, LERF-ISGTR)
- Late (LATE-CHR-AFW, LATE-CHR-NOAFW, LATE-BMMT-AFW, LATE-BMMT-NOAFW)

These groupings were developed to prevent high frequency-low consequence events (i.e., the “Intact” release category) from biasing the importance lists. The release categories included in the review account for 95 percent of the dose-risk while accounting for only about 60 percent of the Level 2 frequency. Exclusion of the other results from the Level 2 review allows the contributors that are most important to dose-risk and cost-risk to rise to the top of the importance lists.

The Level 2 basic events were also reviewed down to the 1.005 level. As described for the Level 1 RRW list, the review threshold was based only on the internal events results given that a separate, explicit review of the fire results was performed for SAMA identification.

Tables F.5-2a and F.5-2b document the disposition of each basic event in the Level 2 RRW lists with RRW values greater than 1.005.

F.5.1.3 INDUSTRY SAMA REVIEW

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

While many of the industry SAMAs reviewed are ultimately shown not to be cost beneficial, some are close contenders and a small number have been estimated to be potentially cost beneficial at other plants. Use of the Braidwood importance ranking should identify the types of changes that would most likely be potentially cost beneficial for Braidwood, but review of selected industry Phase II SAMAs may capture potentially important changes not identified for Braidwood due to PRA modeling differences or SAMAs that represent alternate methods of addressing risk. Given this potential, it was considered prudent to include a review of selected industry Phase II SAMAs in the Braidwood SAMA identification process. In order to improve the likelihood generic Westinghouse issues would be captured and that the SAMAs reviewed would be relevant to the Braidwood design, six Westinghouse PWRs were used as the sources for the SAMAs:

- Vogtle (SNC 2007, NRC 2008a)
- Shearon Harris (CPL 2006, NRC 2008b)
- H.B. Robinson (CPL 2002, NRC 2003a)
- Prairie Island (NMC 2008, NRC 2011)

- Wolf Creek (WCNOC 2006, NRC 2008c)
- Indian Point Unit 2 (Entergy 2007, NRC 2010)

Six Westinghouse PWR sites were chosen from available documentation to serve as the potential Phase 2 SAMA sources. Many of the industry Phase 2 SAMAs were already represented by other SAMAs in the Braidwood list, were known not to impact important plant systems or be relevant to the Braidwood design, or were judged not to have the potential to be close contenders for Braidwood. As a result, they were not added to the Braidwood SAMA list. If there were any unique SAMAs that were considered to have the potential to be cost effective for Braidwood, they were added to the list. The cost effective SAMAs for each of the sites identified above are reviewed in the following subsections.

F.5.1.3.1 Vogtle

Vogtle identified two SAMAs in the baseline analysis that were determined to be potentially cost beneficial. Two additional SAMAs were identified as potentially cost beneficial in the 95th percentile PRA results sensitivity analysis (SAMAs 6 and 16), but after more detailed assessments of the associated implementation costs, it was concluded that SAMAs 6 and 16 were not cost beneficial.

Review of Vogtle Potentially Cost Beneficial SAMAs

Industry Site SAMA ID	SAMA Description	Discussion for Braidwood	Disposition for Braidwood SAMA List
2	Maintain Full Time Black Start Capability of the Plant Wilson Combustion Turbines	There is no local power station with the capability of providing power to the Braidwood switchyard for which operational procedures could be modified to maintain full time black start capability for station blackout (SBO) support. Not applicable.	Not required for the SAMA list
4	Prepare Procedures and Operator Training for Cross-Tying an Opposite Unit DG	Braidwood already has procedures for inter-unit cross-tie of the emergency buses.	Not required for the SAMA list

F.5.1.3.2 Shearon Harris

Review of Shearon Harris Potentially Cost Beneficial SAMAs

Industry Site SAMA ID	SAMA Description	Discussion for Braidwood	Disposition for Braidwood SAMA List
9	Proceduralize Actions to Open EDG Room Doors on Loss of Heating Ventilation and Air-Conditioning (HVAC) and Implement Portable Fans	The EDG room cooling system, which is modeled in the PRA, is not an important contributor to plant risk for Braidwood. No SAMA required.	Not required for the SAMA list
6	Flood Mitigation for Scenarios 6 and 7	This is a plant specific internal flooding issue related to valve qualification in flooding conditions; however, similar issues have not been identified in the review of the Braidwood flooding contributors.	Not required for the SAMA list
8	Alternate Seal Cooling and Direct Feed to Transformer 1B3-SB	This SAMA was developed to address loss of 4kV bus events where power is available to the opposite 4kV bus, but vital equipment has failed on the powered bus. Specifically, it provides an alternate power feed to the bus supporting an available AFW pump and procedure changes to increase the CCW heatup time so that the swing charging pump can be aligned to the opposite power division for seal injection. This SAMA is specific to the Harris configuration where simple procedure changes could be made that would provide adequate time to allow operators to align the swing charging pump to the opposite division of power. There is no equivalent condition for Braidwood and this SAMA is not applicable.	Not required for the SAMA list

F.5.1.3.3 H.B. Robinson

The H.B. Robinson SAMA analysis used a generic SAMA list as its starting point and few plant specific insights were available that might pertain specifically to Westinghouse PWRs. While Carolina Power and Light did not identify any potentially cost beneficial SAMAs, the NRC identified two potentially cost beneficial SAMAs as part of the external events risk review, which are discussed below.

Review of H.B. Robinson Potentially Cost Beneficial SAMAs

Industry Site SAMA ID	SAMA Description	Discussion for Braidwood	Disposition for Braidwood SAMA List
1437-13-1	Replace cast-iron yokes on RHR valves	This is a seismic vulnerability specific to the Robinson configuration. There are no Braidwood RHR components with high confidence of low probability of failure (HCLPF) values below the 0.3g review threshold and the RHR valve yokes were not identified as a potential weakness at Braidwood.	Not required for the SAMA list
1437-13-2	Install a radiant heat shield on the electrical conduit to the shutdown DG	This is a fire vulnerability specific to the Robinson configuration. Braidwood does not have a shutdown DG and this enhancement is not applicable to the site.	Not required for the SAMA list

F.5.1.3.4 Prairie Island Nuclear Generating Plant

Review of Prairie Island Potentially Cost Beneficial SAMAs

Industry Site SAMA ID	SAMA Description	Discussion for Braidwood	Disposition for Braidwood SAMA List
3	Provide Alternate Flowpath from RWST to Charging Pump Suction	Failure of the RWST flowpath to the charging pumps is not a significant contributor for Braidwood. SAMA not required.	Not required for the SAMA list
9	Analyze Room Heat-up for Natural/Forced Circulation (Screenhouse Ventilation)	This SAMA was developed to support the use of alternate room cooling (via a heatup analysis) in the plant’s screenhouse when normal cooling fails. For Braidwood, the loss of screenhouse cooling is not required for any PRA systems. SAMA not required.	Not required for the SAMA list

Review of Prairie Island Potentially Cost Beneficial SAMAs

Industry Site SAMA ID	SAMA Description	Discussion for Braidwood	Disposition for Braidwood SAMA List
19a	Provide a Reliable Backup Water Source for Replenishing the RWST	A SAMA for automated RWST refill was developed for Braidwood based on the PRA importance list review (SAMA 14).	Already included
N/A	Provide a Gagging Device for Closing a stuck-open SG Safety Valve in SGTR Events	Based on information in the DCPP RAI responses (PG&E 2010), gagging devices are installed for maintenance tasks and are useful for preventing PORVs from opening, but are not designed to reclose a stuck open PORV. This SAMA is not considered to be viable and is not included in the Braidwood SAMA list.	Not required for the SAMA list
22	Provide Compressed Air Backup for Instrument Air to Containment	Air systems are modeled for Braidwood, but system failures are not significant contributors to risk. SAMA not required.	Not required for the SAMA list

F.5.1.3.5 Wolf Creek Generating Station

Review of Wolf Creek Generating Station Potentially Cost Beneficial SAMAs

Industry Site SAMA ID	SAMA Description	Discussion for Braidwood	Disposition for Braidwood SAMA List
2	Modify the Controls and Operating Procedures for Sharpe Station to Allow for Rapid Response	There is no local power station with the capability of providing power to the Braidwood switchyard for which operational procedures could be modified to provide rapid start capability for SBO support. Not applicable.	Not required for the SAMA list
4 (case 2)	Update emergency procedures to direct local, manual closure of the RHR EJHV8809A and EJHV8809B valves if they fail to close remotely	This SAMA was developed to address questions about the ability of motor operated valves (MOVs) to close against the differential pressure in a specific ISLOCA sequence for Wolf Creek. Discussions with an Exelon MOV Program engineer indicate that local operation of the valve may be successful depending on several factors. For example, if the motor gearing is the limit, the handwheel may function if enough force could be applied to the handwheel. If other portions of the valve are not capable of withstanding the force required to close, then the isolation will fail. For Braidwood, general training would direct operators to attempt a local valve closure given remote operation failure, so the Wolf Creek SAMA would provide no tangible benefit. A different SAMA (SAMA 19) was developed for Braidwood to replace the 8809 valves (and others) with valves of a different design to ensure a success path is available in ISLOCA scenarios.	Not required for the SAMA list
5	Enhance procedures to direct operators to open EDG Room doors for alternate room cooling	The EDG room cooling system, which is modeled in the PRA, is not an important contributor to plant risk for Braidwood. No SAMA required.	Not required for the SAMA list
1	Permanent, Dedicated Generator for the NCP with Local Operation of TD AFW After 125V Battery Depletion	This was designed to assist in an SBO that included a seal LOCA. The design includes a 4kV, 500kW EDG to power a charging pump and transformer to support the 125V battery chargers. Braidwood does not have a turbine driven AFW pump and the diesel pump requires SX for lube oil cooling, so the SAMA is not applicable to the plant configuration.	Not required for the SAMA list

Review of Wolf Creek Generating Station Potentially Cost Beneficial SAMAs

Industry Site SAMA ID	SAMA Description	Discussion for Braidwood	Disposition for Braidwood SAMA List
3	AC Cross-tie Capability	Braidwood already has 4KV AC cross-tie capability.	Already Implemented
13	Alternate Fuel Oil Tank with Gravity Feed Capability	For Wolf Creek, fuel oil failures contributed significantly to the CDF and an alternate method to transfer fuel to the EDG day tank was determined to be cost effective. The Braidwood fuel oil transfer configuration includes redundant pump trains for each diesel and fuel oil transfer failures are not significant contributors to plant risk. SAMA not required.	Not required for the SAMA list
14	Permanent, Dedicated Generator for the NCP, one Motor Driven AFW Pump, and a Battery Charger	This was designed to assist in an SBO that included a seal LOCA. The design includes a 4kV, 500kW EDG to power a charging pump, an AFW pump, and a transformer to support the 125V battery chargers. For Braidwood, both the charging pumps and the AFW pumps ultimately require SX for cooling and this SAMA would require additional changes to make it applicable to the site. The Diverse Mitigation System (DMS) is proposed as the full scope SBO mitigation enhancement (SAMA 11); however, an alternate design could be investigated that uses a dedicated generator/ seal injection system to prevent seal LOCAs in conjunction with a portable SG makeup pump.	Included as SAMA 26.

F.5.1.3.6 Indian Point Energy Center Unit 2

Review of Indian Point U2 Potentially Cost Beneficial SAMAs

Industry Site SAMA ID	SAMA Description	Discussion for Braidwood	Disposition for Braidwood SAMA List
028	Provide a Portable Diesel Driven Battery Charger	This SAMA was designed to prolong AFW availability in an SBO by using a portable generator to provide alternate battery charging capability. No discussion is provided in the Indian Point U2 SAMA analysis about primary side makeup requirements. The industry initiatives for SBO mitigation, which are commitments, are more comprehensive than this SAMA and are addressed by the “DMS” SAMAs for Braidwood. No additional SAMAs required.	Not required for the SAMA list
044	Use Fire Water System as Backup for Steam Generator Inventory	This enhancement was intended to provide alternate steam generator (SG) makeup capability and relies on Fire Water as a suction source, but includes a new, electric, 800 gpm pump to provide flow. The Fire Water system is a low pressure system that does not address early losses of SG makeup. Braidwood includes a SAMA to complete the AFW X-tie, which addresses the loss of AFW scenarios in a more cost effective manner. No additional SAMAs required.	Not required for the SAMA list
054	Install Flood Alarm in the 480V AC Switchgear Room	Providing a water sensor in the 480V AC Switchgear room would provide early warning of flood conditions and improve the probability isolation could occur before equipment damage. Internal flooding events for the Switchgear Rooms are not significant contributors for Braidwood and are below the review threshold for SAMA identification.	Not required for the SAMA list
056	Keep RHR Heat Exchanger Discharge MOVs Normally Open	The intent of this SAMA is to reduce the contribution of failures of the RHR heat exchanger (HX) valves to open on demand. The Braidwood RHR HX outlet valves are normally open/fail open valves.	Not required for the SAMA list

Review of Indian Point U2 Potentially Cost Beneficial SAMAs

Industry Site SAMA ID	SAMA Description	Discussion for Braidwood	Disposition for Braidwood SAMA List
060	Provide Added Protection Against Flood Propagation from Stairwell 4 into the 480V AC Switchgear Room	This change addresses a plant specific internal flooding issue and includes changes to the swing direction of a door, addition of ductwork, and a check valve. Internal flooding events for the Switchgear Rooms are not significant contributors for Braidwood and are below the review threshold for SAMA identification.	Not required for the SAMA list
061	Provide Added Protection Against Flood Propagation from the Deluge Room into the 480V AC Switchgear Room	This change addresses a plant specific internal flooding issue and includes upgrading the deluge room to close off flood paths. Internal flooding events for the Switchgear Rooms are not significant contributors for Braidwood and are below the review threshold for SAMA identification.	Not required for the SAMA list
065	Upgrade the Alternate Safe Shutdown System to Allow Timely Restoration of Seal Injection and Cooling	This SAMA involves providing a hardwired connection from the Alternate Safe Shutdown System power supply to a safety injection (SI) pump to improve the probability that the operators can restore RCP seal cooling in a timely manner. Braidwood does not have a similar system that could be enhanced for this function and the SAMA is not applicable to the site as written. However, SAMA 2, which was identified based on the PRA results, involves replacing existing equipment to provide an alternate means of seal cooling on failure of the running systems.	Already included

F.5.1.3.7 Industry SAMA Identification Summary

The important issues for Braidwood are generally considered to be addressed by the SAMAs developed through the PRA importance list review. The plant changes suggested as part of that review were developed to meet the specific needs of the plant such that those SAMAs are more likely to provide effective means of risk reduction than SAMAs taken from other sites. However, effort was made to review other industry SAMA analyses to determine if other sites identified plant changes that could be potentially cost beneficial for Braidwood based on modeling differences or other factors. For Braidwood, the industry review identified a potential alternate design for the implementation of the diverse mitigation system (DMS) that has been included in the Phase 1 SAMA list for consideration:

- DMS Using a Dedicated Generator, Self-Cooled Charging Pump, and a Portable AFW Pump (SAMA 26)

F.5.1.4 BRAIDWOOD IPE PLANT IMPROVEMENT REVIEW

The Braidwood IPE, unlike many industry IPEs, did not document a definitive list of proposed plant enhancements. Instead, the IPE describes the Commonwealth Edison (ComEd) accident management program and how it was used to assess the IPE and Accident Management insights from the Byron, Braidwood and other ComEd plant IPEs, which were assessed together given that the insights were generally considered to be applicable to both the Byron and Braidwood sites. The discussion indicates that over 220 IPE and Accident Management insights were developed that were potentially applicable to PWRs and that they were evaluated by the review team; however, these insights are not specifically provided. A plant enhancement that is described in the IPE, a procedure modification to direct inter-unit 4 kV AC emergency bus cross-tie in non-SBO scenarios, was evaluated as part of the IPE process. The IPE includes a section documenting the impact of implementing the procedure, which was subsequently implemented at the site. One additional procedure enhancement, which was grouped in the Accident Management Guidance category, is described in the IPE. The insight was to update the plant procedures to direct reactor cavity flooding in core damage scenarios to provide a means of exterior vessel cooling. The IPE states that this potential procedure change was to be evaluated as part of the implementation of the Westinghouse Owner's Group Severe Accident Management Guidance. No other specific proposed plant changes were identified in the IPE. The table below summarizes the status of these changes for Braidwood:

Status of IPE Plant Enhancements

Description of Potential Enhancement	Status of Implementation	Disposition
Modify plant procedures to allow inter-unit cross-tie for non-SBO conditions	Implemented	No further evaluation required.
Update severe accident guidelines to direct reactor cavity flooding to prevent reactor vessel failure	Implemented	No further evaluation required.

The limited number of plant changes explicitly suggested in the IPE has been implemented at Braidwood and therefore no further review of these items is required.

F.5.1.5 BRAIDWOOD IPEEE PLANT IMPROVEMENT REVIEW

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

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

Status of IPEEE Plant Enhancements

Description of Potential Enhancement	Status of Implementation	Disposition
Control room ceiling diffusers are made of aluminum and, if dislodged by a seismic event, may pose a personnel hazard (seismic)	Resolved.	No SAMAs Required
Multiple MCCs, battery chargers, and breakers were found not to be tied together posing an impact issue (seismic).	Resolved.	No SAMAs Required.

The above plant changes suggested in the IPEEE have been resolved by the site and no further review is required.

F.5.1.6 EXTERNAL EVENTS IN THE BRAIDWOOD SAMA ANALYSIS

The IPEEE was used in the Braidwood SAMA analysis primarily to identify the highest risk accident sequences and the potential means of reducing the risk posed by those sequences. The types of events considered in the Braidwood external events analysis were identified by NUREG-1470 (NRC 1991) and included:

- Internal Fires
- Seismic Events
- High Winds and Tornadoes
- External Flooding
- Transportation and Nearby Facility Accidents
- Rail Transportation Accidents (treated as part of transportation and nearby facility accidents)
- Barge Transportation Accidents

- Pipeline Transportation Accidents
- Military Facilities
- On-site Hazardous Material Accidents
- Severe Temperature Transients
- Severe Weather Storms
- Lightning Strikes
- External Fires
- Extraterrestrial Activity
- Volcanic Activity
- Abrasive Windstorms

These potential contributors were evaluated using a progressive screening approach, per NUREG-1407, which resulted in the screening of most initiator types, but designated five initiators for further analysis:

- Internal Fires (Section F.5.1.6.1)
- Seismic Events (Section F.5.1.6.2)
- High Wind Events (Section F.5.1.6.3)
- External Floods (Section F.5.1.6.4)
- Transportation and Nearby Facility Accidents (Section F.5.1.6.5)

The external event types that were not explicitly evaluated in the IPEEE for Braidwood are considered to be negligible contributors to risk and they are excluded from further consideration in the SAMA identification process.

The types of information available for the initiators that were evaluated by Braidwood varies based on the manner in which they were addressed in the IPEEE and the Fire model. For instance, core damage frequency information was developed as part of the fire risk analysis while the seismic margins analysis does not directly provide any core damage frequency estimates. Finally, a progressive screening approach was employed to address the other external events contributors that were considered to be applicable to the site and no quantitative information is available for those events.

While CDF results are available for fire events, the results are not necessarily compatible with those of the internal events analysis. For example, the Fire model is based on the NUREG/CR-6850 (EPRI 2005) methodology, which includes conservative approaches to address areas of uncertainty. This model is also in the development stage and it is not considered to be mature enough to use as a quantitative basis for detailed risk assessments. Finally, the fire model is not linked to the Level 2 PRA model and the consequences of the corresponding core damage scenarios are not available.

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

F.5.1.6.1 Internal Fires

As discussed above, the techniques used to model external events vary according to the type of initiator being analyzed. For Braidwood, the 2008 Braidwood Fire PRA (Exelon 2008a) is available for use in the SAMA analysis, but the model is considered to be an interim implementation of NUREG/CR-6850 given that not all tasks identified in that document are completely addressed or implemented in model. This was due to the graded approached used to develop the analysis and to the changing state-of-the-art methodologies at the time the analysis was developed.

The approach taken for the SAMA analysis is to use the fire model results to develop potential SAMAs and to use risk insights from both the fire and internal events PRA models to approximate potential averted cost-risk for the SAMAs. Even if it was considered appropriate to use the fire results directly for SAMA quantification, the fire model is not integrated with the most recent Level 2 and 3 analyses that are available to support the SAMA analysis, which prevents the evaluation of accident consequences in a manner consistent with the process used for the internal events models. Finally, the fire model is based on a previous revision of the PRA (Revision 6C) rather than the current revision (BB011b1), which introduces additional area of inconsistency.

While the fire model results are not necessarily comparable to the current PRA results, the SAMA analysis directly uses the fire CDF to develop the external events multiplier, as described in Section F.4.6.2.

The SAMA identification process for the fire model uses an IPEEE screening criterion to identify those fire contributors that are potentially significant to risk. Specifically, any fire zone with a CDF greater than the IPEEE screening threshold of 1.0E-06/yr was reviewed to identify potential SAMAs. Review of additional fire scenarios is possible, but this approach was chosen to limit the review of the interim model results to the largest contributors (the top 14 fire zones for Unit 1 and the top 18 fire zones for Unit 2 (32 fire zones in all)).

The fire CDFs used to identify the fire zones for review are based on the Braidwood fire PRA scenario results modified to account for the use of the more recent fire ignition frequencies from EPRI 1016735 (EPRI 2008). The fire scenario results for each zone were reviewed and grouped together to help identify target equipment that is common to multiple scenarios in a given fire zone. The reviews were performed and documented separately for the two units given that there are differences between them. The following tables provide a list of the fire zones with CDFs greater than 1.0E-06/yr.

Major Braidwood Unit 1 Fire Contributors

Fire Zone	Major Scenarios	Zone Description	CDF
1-1	A	UNIT 1 CONTAINMENT	7.02E-06
11.3-1	B	Unit 1 containment pipe penetration area	5.74E-06
11.3-0	K	Auxiliary building general area, elv. 364	5.66E-06
11.4c-0	D	Radwaste and remote shutdown panel control room	5.25E-06
11.6-1	D	Division 12 containment electrical penetrations area	3.68E-06
5.2-1	E	Division 11 ESF switchgear room	3.21E-06
5.6-1	E, H	Division 11 Miscellaneous electric equipment room and battery room	3.18E-06
5.5-1	AE, D, E, Q	Unit 1 auxiliary electric equipment room	2.50E-06
5.6-2	D	Division 21 Miscellaneous electric equipment room and battery room	2.06E-06
5.1-1	B, E	Division 12 Engineered Safety Features (ESF) switchgear room	1.53E-06
11.6c-0	A	Auxiliary building laundry room	1.49E-06
18.12-0	A	Circ water pump house (Byr)/Lake screen house (Bdw)	1.26E-06
11.6-0	L, H	Auxiliary building general area, elv. 426	1.20E-06
11.5a-1	B	Division 11 containment electrical penetrations area	1.05E-06

Major Braidwood Unit 2 Fire Contributors

Fire Zone	Major Scenarios	Zone Description	CDF
5.2-2	G, B	Division 21 ESF switchgear room	7.84E-06
11.4C-0	C, I	Radwaste and remote shutdown panel control room	6.05E-06
1-2	A	UNIT 2 CONTAINMENT	4.88E-06
5.6-1	E	Division 11 Miscellaneous electric equipment room and battery room	4.61E-06
5.6-2	D	Division 21 Miscellaneous electric equipment room and battery room	3.73E-06
11.6-2	C	Division 22 containment electrical penetrations area	3.44E-06
5.5-2	R, Z, P	Unit 2 auxiliary electric equipment room	3.13E-06
5.2-1	B, C	Division 11 ESF switchgear room	2.22E-06
11.6-0	H, O	Auxiliary building general area, elv. 426	1.75E-06
11.5A-2	B, D	Division 21 containment electrical penetrations area	1.64E-06
11.4-0	E, B	Auxiliary building general area, elv. 383	1.45E-06
18.12-0	A	Circ water pump house (Byr)/Lake screen house (Bdw)	1.32E-06
11.5-0	R	Auxiliary building general area, elv. 401	1.24E-06
1-1	A	UNIT 1 CONTAINMENT	1.21E-06
11.6C-0	A	Auxiliary building laundry room	1.2E-06
18.10E-2	B, D, C	System auxiliary transformers 242-1 and 242-2	1.08E-06
18.10E-1	B, D, C	System auxiliary transformers 142-1 and 142-2	1.08E-06
8.6-0	A	Turbine building operating floor	1.02E-06

For each fire zone with a CDF greater than 1.0E-06/yr, the contributing risk factors were reviewed to determine what measures could be taken to mitigate the fire event and the corresponding core damage sequences. Further discussion is provided for each of these fire compartments below.

UNIT 1

U1: 1-1 (Scenario A), Unit 1 Containment

In this "bounding" fire scenario, the fire induced failures include a LOCA through the reactor head vent, failure to re-seat of the PORVs, failure of the block valves to open (if they are initially closed), failure of the low pressurizer pressure signal for SI, and failure of the high pressure recirculation suction path for both divisions of the CV/SI pumps (through CV8804A and SI8804B), and loss of the RCFC low speed mode on all fans.

For the cases in which AFW is successful, recirculation mode is ultimately required for success due to the fire induced small LOCA condition, but having the ability to perform cooldown using secondary side heat removal provides an additional path to success that does not require the pressurizer PORVs. As a result, improving AFW reliability, which could be accomplished by implementing the AFW cross-tie (SAMA 15), would significantly reduce the risk of these scenarios (about 90%). Another potential means of reducing the risk of these scenarios would be to provide makeup capability to the RWST to increase the time available for system cooldown to be performed (SAMA 14).

Because the fire is a "bounding" scenario, fire scenarios are not developed for all of the specific ignition sources in the fire zone, which limits the potential for fire specific SAMA identification. Given that the RCPs are the largest contributors to the ignition frequency, a potential means of reducing the fire frequency would be through a mechanism to prevent the fire. Incipient fire detectors are a potential means of accomplishing this goal; however, the reliability of incipient detectors to prevent fires has neither been established nor accepted in the industry, and this enhancement is not suggested as a SAMA.

U1: 11.3-1 (Scenario B), Unit 1 Containment Pipe Penetration Area

Fires in this scenario essentially fail all high pressure injection (HPI), division 1 recirculation, division 1 secondary side heat removal, RCP seal cooling to 2 of 4 pumps directly and the remaining 2 by loss of RWST inventory to the sump (with failure of the volume control tank (VCT) path).

The fire ignition source for this scenario is MCC 131X1, the failure of which results in the loss of the equipment identified above. Because the fire induced failures identified above are the result of damage to the ignition source for the fire scenario, the means of preventing loss of the equipment is limited to enhancements that prevent the fire from developing. Incipient fire detectors are a potential means of accomplishing this goal; however, the reliability of incipient detectors to prevent fires has neither been established nor accepted in the industry, and this enhancement is not suggested as a SAMA.

Installation of no leak RCP seals (SAMA 4) would prevent primary side inventory loss and reduce the risk from these fire scenarios. Completing the implementation of the AFW cross-tie enhancement would provide an alternate means of secondary side heat removal (SAMA 15).

U1: 11.3-0 (Scenario K), Auxiliary building general area, elv. 364

This fire scenario fails the heat removal medium for recirculation mode and fails the alternate room cooling for the division 2 injection pumps. Enhancements that would reduce the risk of these scenarios include SAMAs that improve secondary side heat removal capability and those that prevent seal LOCAs. Potential SAMAs include replacing the positive displacement pump (PDP) with a self-cooled, auto start pump for alternate RCP seal cooling (SAMA 2), installation of no-leak RCP seals (SAMA 4), modifying the startup Feedwater pump to auto start on low SG level (SAMA 5), installing alternate AFW pump cooling in conjunction with alternate RCP seal cooling (SAMA 13), completing the AFW crosstie (SAMA 15), and automating refill of the diesel driven AFW fuel oil tank (SAMA 18).

Fire scenario K is caused by a fire in MCC 132X1, which does propagate to other equipment. The cables for the RH, SI, and CVCS pump cubicle cooler fans could potentially be protected to improve the likelihood that they will be available for injection and seal cooling (SAMA 27).

U1: 11.4c-0 (Scenario D), Radwaste and Remote Shutdown Panel Control Room

This fire scenario includes seal cooling failure, AFW failure, high pressure injection failure (CVCS), and failure of the Unit 1 SX system (no containment heat removal).

These failures can potentially be mitigated by the DMS; the portable SG injection pump can be used to provide SG makeup and the “no leak” seals would maintain primary side inventory with makeup from an alternate 480V pump (SAMA 11). Installation of a diesel driven SX pump could also provide a potential success path (SAMA 1).

For this scenario, the ignition sources are the Unit 1 remote shutdown control panels (1PL04J, 1PL05J and 1PL06J). Because the fire induced failures identified above are the result of damage to the ignition source for the fire scenario, the means of preventing loss of the equipment is limited to enhancements that prevent the fire from developing. Incipient fire detectors are a potential means of accomplishing this goal; however, the reliability of incipient detectors to prevent fires has neither been established nor accepted in the industry, and this enhancement is not suggested as a SAMA.

U1: 11.6-1 (Scenario D), Division 12 Containment Electrical Penetrations Area

This fire scenario includes degradation of seal cooling capability, degradation of AFW makeup capability, RWST draindown to the sump, degradation of high pressure recirculation capability, and degradation of the service water system.

The risk from this scenario could potentially be mitigated by improving the reliability of FW restoration and preventing and RCP seal LOCA. In addition, providing mode service water flexibility could improve the plant response. Modifying the startup FW pump to auto start and align on low SG level would provide a means of maintaining secondary side cooling on AFW failure (SAMA 5). Loss of seal cooling could be mitigated by the installation of “no leak” RCP seals (SAMA 4). The SX system availability could be improved by adding a diesel driven SX pump (SAMA 1).

Fire scenario D is caused by a fire in MCC 132X4, which itself does not result in the loss of many significant loads, but there are multiple targets near the MCC that will fail as a result of the fire. This scenario could potentially be mitigated by the installation of fire barriers to protect nearby equipment (SAMA 28).

U1: 5.2-1 (Scenario E), Division 11 ESF Switchgear Room

This fire scenario results in failure of the “A” division 480V ESF bus, which results in long term battery depletion and loss of “A” division DC power in addition to the loss of numerous other critical 480V AC loads.

The risk from this scenario could potentially be mitigated by improving the reliability of DC power on the remaining division, which could include use of the DMS as a backup power supply (SAMA 11). The DMS also mitigates the largest contributor to the conditional core damage probability, which is failure of the B AFW pump.

Fire scenario E is caused by a fire in MCC 131X, which results in the loss of the critical loads for this scenario. Because the fire induced failures identified above are the result of damage to the ignition source for the fire scenario, the means of preventing loss of the equipment is limited to enhancements that prevent the fire from developing. Incipient fire detectors are a potential means of accomplishing this goal; however, the reliability of incipient detectors to prevent fires has neither been established nor accepted in the industry, and this enhancement is not suggested as a SAMA.

U1: 5.6-1 (Scenarios E, H), Division 11 Miscellaneous Electric Equipment Room and Battery Room

This fire scenario results in failure of the "A" division 125V DC bus, which leads to the failure of many critical division "A" loads, including AFW and RHR.

The risk from this scenario could potentially be mitigated by improving the reliability of the secondary side heat removal function, which could be performed by completing the implementation of the AFW cross-tie (SAMA 15).

Fire scenario E is caused by a fire in DC Bus 111, which is important due to the loads it carries. Because many of the fire induced failures identified above are the result of damage to the ignition source for the fire scenario, the means of preventing loss of the equipment is limited to enhancements that prevent the fire from developing. Incipient fire detectors are a potential means of accomplishing this goal; however, the reliability of incipient detectors to prevent fires has neither been established nor accepted in the industry, and this enhancement is not suggested as a SAMA. Scenario H is initiated in inverter 111. This scenario could potentially be mitigated by sealing the panel and installing fire barriers to protect nearby equipment (SAMA 29).

U1: 5.5-1 (Scenarios AE, D, E, Q), Unit 1 Auxiliary Electric Equipment Room

The largest contributor, fire scenario "AE", results in failure of both AFW pumps, as do scenarios "D" and "E". Scenario Q fails the "A" train of AFW and includes random failures of the "B" train. The DMS could potentially provide alternate secondary side heat removal capability, but operator action dependence issues would limit its benefit for the largest contributors (e.g., with recirculation start or RH pump trip for pump operation without CC flow to the RH HX). Primary system cooling is available for these fire scenarios, but the operator failures lead to core damage. The Auxiliary Electric Equipment Room includes a large number of electrical cabinets and other equipment that serve as diverse ignition sources and mechanisms for fire propagation. Installation of fire barriers may be possible, but there are other options that appear to be less complex and more cost effective. SAMAs that could reduce the risk of these scenarios include a procedure change to align CCW flow to the RH Heat Exchanges on RH pump start (SAMA 7) and automating the swap to recirculation mode (SAMA 30).

U1: 5.6-2 (Scenario D), Division 21 Miscellaneous Electric Equipment Room and Battery room

This scenario is the result of a fire initiating in Unit 2 battery charger 211 or the associated bus (211), which disables the inter-unit DC cross-tie as well as DC bus 111 on Unit 1. The core damage scenarios include failures of the "B" division equipment required to support primary and secondary side heat removal, such as AFW pump B failure to start/run and failure of the pressurizer PORVs to open. Some of the contribution is related to operator error, but implementation of the DMS would provide a means of mitigating many of these scenarios (SAMA 11).

The fire induced damage is primarily the result of the loss of the ignition source, so fire barriers would provide little benefit for this scenario. Because many of the fire induced failures identified above are the result of damage to the ignition source for the fire scenario, the means of preventing loss of the equipment is limited to enhancements that prevent the fire from developing. Incipient fire detectors are a potential means of accomplishing this goal; however, the reliability of incipient detectors to prevent fires has neither been established nor accepted in the industry, and this enhancement is not suggested as a SAMA.

U1: 5.1-1 (Scenarios B, E), Division 12 ESF Switchgear Room

These scenarios are the result of a fire initiating in the “B” 4KV ESF bus or the “B” 480V ESF bus. These fires essentially eliminate an entire division of equipment. The largest contributors to these fire scenarios are failures of the SX system, including operator failure to start the standby SX pump on loss of the running pump, “A” SX pump maintenance, and failure of the “A” SX pump min flow path. These failures could be mitigated by installing a diesel driven SX pump train (SAMA 1) or automating start of the standby SX pump on low pressure (SAMA 3). Implementation of the DMS would also provide an alternate means of providing heat removal without SX (SAMA 11).

U1: 11.6c-0 (Scenario A), Auxiliary building laundry room

This scenario is a bounding fire that is based on the total initiating event frequency for the zone, which in this zone is totally comprised of transient initiators.

The consequences of the fire are fairly broad and include division 1 power (including the 141-241 4 kV X-tie) and multiple failures of division 1 equipment (which are already unavailable due to the power failure).

The largest contributors to the consequential CDF for this scenario are failures of the division 2 AFW pump, division 2 SX equipment failures, and division 2 RHR system failures.

These failures can potentially be mitigated by the DMS; the portable SG injection pump can be used to provide SG makeup and the “no leak” seals would maintain primary side inventory (SAMA 11).

No practical SAMAs have been identified to prevent the transient fires in this fire zone and because the fire is a bounding fire, no specific information is available regarding fire propagation or ignition sources that would help identify effective equipment protection methods.

U1: 18.12-0 (Scenario A), Lake Screen House

This scenario is a bounding fire that is based on the total initiating event frequency for the zone. The consequence of the fire is a loss of the diesel fire pump, which has a limited impact on the results. In general, improving the reliability of the AFW system would reduce the frequency of the fire scenario, which could be accomplished by completing the implementation of the AFW cross-tie (SAMA 15) or using anticipated transient without scram mitigating system actuation circuitry (AMSAC) as a backup AFW start signal (SAMA 17). The diesel fire pump itself is primarily used to provide alternate lube oil cooling to the charging pumps for seal LOCA prevention, but for this fire scenario, seal LOCAs are less than a 1% contributor to the conditional core damage probability.

U1: 11.6-0 (Scenarios L, H), Aux Building General Area, Elevation 426'

These scenarios are initiated in different 480V MCCs that lead to failure of multiple functions; the H scenarios impacts division 1 equipment while the L scenarios impacts division 2 equipment. While the specific list of impacted equipment is not the same for both scenarios, the functional impacts are similar. The L scenario fails AFW, RHR, CCW, and CVCS of the noted division and seal LOCAs are top contributors. The H scenario is similar for the opposite train and seal LOCAs are also large contributors as well as a head vent LOCA due to spurious valve openings.

The “L” scenario failures can potentially be mitigated by the DMS; the portable SG injection pump can be used to provide SG makeup and the “no leak” seals would maintain primary side inventory (SAMA 11).

In addition, a large contributor for scenario L is the operator failure to stop the RH pump when it is running without CC flow to the heat exchanger. A potential means of reducing the risk of this scenario is to change the procedures to direct initiation of CC flow to the RH heat exchangers when the pumps start (SAMA 7).

For the “H” scenario cases in which AFW is successful, recirculation mode is ultimately required for success due to the fire induced small LOCA condition, but having the ability to perform cooldown using secondary side heat removal provides an additional path to success that does not require the pressurizer PORVs. As a result, improving AFW reliability, which could be accomplished by implementing the AFW cross-tie (SAMA 15), would significantly reduce the risk of these scenarios. Another potential means of reducing the risk of these scenarios would be to provide makeup capability to the RWST to increase the time available for system cooldown to be performed (SAMA 14).

There are targets both above and around both of the ignition sources for these fires and the installation of fire barriers around MCCs 132X5 and 134X could potentially reduce the risk of these scenarios (SAMA 31).

U1: 11.5a-1 (Scenario B), Division 11 Containment Electrical Penetrations Area

This scenario, which is initiated in 480V MCC 131X2, leads to a failure of multiple division 1 systems/functions, including: AFW, the sump suction path for recirculation mode, the normal CVCS high pressure recirculation suction path, and thermal barrier cooling.

The largest contributor to the conditional core damage probability (33%) is the failure of the division 2 AFW pump, which forces feed and bleed and recirculation mode for heat removal. These failures can potentially be mitigated by the DMS; the portable SG injection pump can be used to provide SG makeup and the “no leak” seals would maintain primary side inventory (SAMA 11). About 12% is related to the failure to establish recirculation model. Fully automating the swap to recirculation mode would help mitigate this issue (SAMA 30).

There are significant targets both above and around each ignition source for this scenario and the installation of fire barriers around MCC 131X2 could potentially reduce the risk of these fires (SAMA 32).

UNIT 2

U2: 5.2-2 (Scenarios G, B), Division 21 ESF Switchgear Room

These fire scenarios result in wide range of failures that essentially eliminate an entire division (division 1) of equipment and the division 1 inter-unit 4kV cross-tie.

One of the larger contributors to the conditional core damage probability for the scenario is the operator failure to refill the DG B fuel oil tank (about 30%). Automating the refill capability would help reduce the risk from these fires (SAMA 18). A contributor of approximately 20% is failure to start the standby SX pump on loss of the initially running pump; this could be addressed by automating start of the standby pump (SAMA 3). Another contributor is the failure of the operators to establish a cool suction source for the charging pumps on loss of SW. Replacing the existing PDP with a self-cooling charging pump with auto start capability would mitigate these scenarios (SAMA 2). Installation of “no-leak” RCP seals is another means of addressing the failure of seal cooling (SAMA 4).

Fire scenario B is caused by a fire in 4160V switchgear 241, which results in the loss of most of the critical loads for this scenario. Because the fire induced failures identified above are the result of damage to the ignition source for the fire scenario, the means of preventing loss of the equipment is limited to enhancements that prevent the fire from developing. Incipient fire detectors are a potential means of accomplishing this goal; however, the reliability of incipient detectors to prevent fires has neither been established nor accepted in the industry, and this enhancement is not suggested as a SAMA. Fire scenario G occurs in the 231X switchgear and similarly, the impact from this fire is mostly caused by loss of the ignition source.

U2: 11.4C-0 (Scenarios C, I), Radwaste and Remote Shutdown Panel Control Room

This fire scenario includes seal cooling failure, AFW failure, high pressure injection failure (CVCS), and failure of the Unit 2 SX system (no containment heat removal).

These failures can potentially be mitigated by the DMS; the portable SG injection pump can be used to provide SG makeup and the “no leak” seals would maintain primary side inventory with makeup from an alternate 480V pump (SAMA 11). Installation of a diesel driven SX pump could also provide a potential success path (SAMA 1).

For this scenario, the ignition sources are the Unit 2 remote shutdown control panels (2PL04J, 2PL05J and 2PL06J). Because the fire induced failures identified above are the result of damage to the ignition source for the fire scenario, the means of preventing loss of the equipment is limited to enhancements that prevent the fire from developing. Incipient fire detectors are a potential means of accomplishing this goal; however, the reliability of incipient detectors to prevent fires has neither been established nor accepted in the industry, and this enhancement is not suggested as a SAMA.

U2: 1-2 (Scenario A), Unit 2 Containment

In this “bounding” fire scenario, the fire induced failures include a LOCA through the reactor head vent, failure to re-seat of the PORVs, failure of the block valves to open (if they are initially closed), failure of the low pressurizer pressure signal for SI, and failure of the high pressure recirculation suction path for both divisions of the CV/SI pumps (through CV8804A and SI8804B), and loss of the RCFC low speed mode on all fans.

For the cases in which AFW is successful, recirculation mode is ultimately required for success due to the fire induced small LOCA condition, but having the ability to perform cooldown using secondary side heat removal provides an additional path to success that does not require the pressurizer PORVs. As a result, improving AFW reliability, which could be accomplished by implementing the AFW cross-tie (SAMA 15), would significantly reduce the risk of these scenarios (about 90%). Another potential means of reducing the risk of these scenarios would be to provide makeup capability to the RWST to increase the time available for system cooldown to be performed (SAMA 14).

Because the fire is a “bounding” scenario, fire scenarios are not developed for all of the specific ignition sources in the fire zone, which limits the potential for fire specific SAMA identification. Given that the RCPs are the largest contributors to the ignition frequency, a potential means of reducing the fire frequency would be through a mechanism to prevent the fire. Incipient fire detectors are a potential means of accomplishing this goal; however, the reliability of incipient detectors to prevent fires has neither been established nor accepted in the industry, and this enhancement is not suggested as a SAMA.

U2: 5.6-1 (Scenario E), Division 11 Miscellaneous Electric Equipment Room and Battery Room

This fire scenario results in failure of the “A” division 125V DC bus, which leads to the failure of many critical division “A” loads, including AFW and RHR.

The risk from this scenario could potentially be mitigated by improving the reliability of the secondary side heat removal function, which could be performed by completing the implementation of the AFW cross-tie (SAMA 15).

Fire scenario E is caused by a fire in 125V DC buss 111, which is important due to the failure of DC bus 211 that is causes. Because this failure is the result of damage to the ignition source for the fire scenario, the means of preventing loss of the equipment is limited to enhancements that prevent the fire from developing. Incipient fire detectors are a potential means of accomplishing this goal; however, the reliability of incipient detectors to prevent fires has neither been established nor accepted in the industry, and this enhancement is not suggested as a SAMA.

U2: 5.6-2 (Scenario D), Division 21 Miscellaneous Electric Equipment Room and Battery room

This scenario is the result of a fire initiating in Unit 2 battery charger 211 or the associated bus (211), which disables the inter-unit DC cross-tie as well as DC bus 111 on Unit 1. The core damage scenarios include failures of the “B” division equipment required to support primary and secondary side heat removal, such as AFW pump B failure to start/run and failure of the pressurizer PORVs to open. Some of the contribution is related to operator error, but implementation of the DMS would provide a means of mitigating many of these scenarios (SAMA 11).

The fire induced damage is primarily the result of the loss of the ignition source, so fire barriers would provide little benefit for this scenario. Because many of the fire induced failures identified above are the result of damage to the ignition source for the fire scenario, the means of preventing loss of the equipment is limited to enhancements that prevent the fire from developing. Incipient fire detectors are a potential means of accomplishing this goal; however, the reliability of incipient detectors to prevent fires has neither been established nor accepted in the industry, and this enhancement is not suggested as a SAMA.

U2: 11.6-2 (Scenario C), Division 22 Containment Electrical Penetrations Area

This scenario is initiated in 480V MCC 232X4, which leads to the loss of a wide range of division 2 equipment, including AFW, SI, RHR, the 2B EDG, the 2A charging pump, and SX. These failures result in a loss of RCP seal cooling, which results in an RCP seal LOCA in about 90% of the contributors.

Installing the “no-leak” seals is a potential means of addressing this fire scenario (SAMA 4). Implementation of the DMS would also address the cases in which the seals do not fail through the SG makeup capability, but the cost of the additional scope of the DMS for only 10% of this fire scenario would not be cost beneficial. About 15% of the contribution is associated with the failure to stop the RH pumps when CC is not flowing to the RH heat exchangers. A potential means of reducing the risk of this scenario is to change the procedures to direct initiation of CC flow to the RH heat exchangers when the pumps start (SAMA 7).

The fire induced damage is primarily the result of the loss of the ignition source, so fire barriers would provide little benefit for this scenario. Because many of the fire induced failures identified above are the result of damage to the ignition source for the fire scenario, the means of preventing loss of the equipment is limited to enhancements that prevent the fire from developing. Incipient fire detectors are a potential means of accomplishing this goal; however, the reliability of incipient detectors to prevent fires has neither been established nor accepted in the industry, and this enhancement is not suggested as a SAMA.

U2: 5.5-2 (Scenarios R, Z, P), Unit 2 Auxiliary Electric Equipment Room

The largest contributor, fire scenario “R”, results in failure of AFW and the division 1 charging pump such that failures of feed and bleed and recirculation model dominate the results. The largest contributors are operator actions to align recirculation mode and to stop the RHR pumps when they are running without CC cooling to the heat exchangers. SAMAs that could reduce the risk of these scenarios include a procedure change to align CCW flow to the RH Heat Exchanges on RH pump start (SAMA 7) and automating the swap to recirculation mode (SAMA 30).

The “P” scenario includes fire induced failures of AFW A, RCP seal cooling, and DG 2A. Larger contributors to the conditional core damage probability include operator failures to refill the “B” AFW fuel oil tank, align recirculation mode, and to stop the RHR pumps when they are running without CC cooling to the heat exchangers. SAMAs that could reduce the risk of these scenarios include automating the AFW diesel fuel oil refill function (SAMA 18), a procedure change to align CCW flow to the RH Heat Exchanges on RH pump start (SAMA 7), and automating the swap to recirculation mode (SAMA 30). Completing the AFW cross-tie would also impact about 40% of the risk (SAMA 15). Also, RCP seal LOCAs comprise about 50% of the risk. These contributors could be addressed with “no-leak” RCP seals (SAMA 4) or the DMS (SAMA 11).

The “Z” scenario includes failure of both AFW pumps and a majority of the conditional core damage probability is associated with two operator actions: failure to align recirculation mode, and failure to stop the RHR pumps when they are running without CC cooling to the heat exchangers. SAMAs that could reduce the risk of these scenarios include a procedure change to align CCW flow to the RH Heat Exchanges on RH pump start (SAMA 7), and automating the swap to recirculation mode (SAMA 30).

U2: 5.2-1 (Scenarios B, C), Division 11 ESF Switchgear Room

The larger contributor, fire scenario “B”, is initiated in 4KV bus 141, which results in failure of bus 241 and essentially all division 1 equipment in addition to division 2 AFW.

Scenario “C” is initiated in bus 143 and results in failure of the feed to 4KV bus 241, which makes all division 1 safety related equipment unavailable.

The failure contributions to both scenarios are diverse and no single failure contributes more that 10% to the total condition core damage probability. In these cases, the SG makeup function is important, but the Unit 1 fires would likely preclude the availability of the AFW cross-tie and SAMA 15 is not proposed for these events. The DMS could provide SG makeup capability (SAMA 11).

In scenario B, damage to the Unit 2 equipment occurs due to cable connections to the ignition source and the means of preventing loss of the equipment is limited to enhancements that prevent the fire from developing. Incipient fire detectors are a potential means of accomplishing this goal; however, the reliability of incipient detectors to prevent fires has neither been established nor accepted in the industry, and this enhancement is not suggested as a SAMA. For scenario “C”, installing cable wrap on the cross-tie cable to bus 241 may prevent loss of the Unit 2 bus (SAMA 33).

U2: 11.6-0 (Scenarios H, O), Aux Building General Area, Elevation 426’

Scenario “H” is initiated in Unit 1 480V MCC 134X, which fails multiple Unit 1 loads, AFW B, and 4KV bus 241 (all division 1 safety related loads). In addition, Scenario “H” includes a head vent LOCA caused by spurious valve operation. Scenario “O” is initiated in Unit 2 480V MCC 231X5, which in addition to its loads (SX flow to some RCFC coolers, VCT suction for charging, and the RHR pump 2A cubicle cooler), fails the 2A SX pump.

The failure contributions to scenario “H” are diverse and no single failure contributes more that 10% to the total condition core damage probability. In these cases, the SG makeup function is important, but the Unit 1 fires would likely preclude the availability of the AFW cross-tie and SAMA 15 is not proposed for these events. A potential alternative means of reducing the risk of these scenarios would be to provide makeup capability to the RWST to increase the time available for system cooldown to be performed (SAMA 14).

Scenario “O” includes a 30% contribution from operator failure to manually start AFW on loss of the auto start signal. These events could potentially be addressed by adding a diverse start signal from AMSAC (SAMA 5). The DMS could provide SG makeup capability (SAMA 11), but only for the cases in which AFW failure is not due to operator error. Failure to start the standby SX pump on failure of the running pump could be addressed by automating start of the standby SX pump on loss of SX flow (SAMA 3).

For scenario “H”, installing cable wrap on the cross-tie cable to bus 241 may prevent loss of the Unit 2 bus (SAMA 34).

In scenario “O”, the fire induced damage is primarily the result of the loss of the ignition source, so fire barriers would provide little benefit for this scenario. Because many of the fire induced failures identified above are the result of damage to the ignition source for the fire scenario, the means of preventing loss of the equipment is limited to enhancements that prevent the fire from developing. Incipient fire detectors are a potential means of accomplishing this goal; however, the reliability of incipient detectors to prevent fires has neither been established nor accepted in the industry, and this enhancement is not suggested as a SAMA.

U2: 11.5a-2 (Scenarios B, D), Division 21 Containment Electrical Penetrations Area

The larger contributor, fire scenario "B", is initiated in 480V MCC 231X2, which results in failure of AFW "A", thermal barrier cooling, the division 1 sump suction path, and the normal high pressure recirc suction path, along with other failures. For scenario "B", a majority contributor is the operator error to refill the AFW fuel oil tank for AFW pump "B". Automating the refill function would reduce the contribution of these scenarios (SAMA 18). AFW "B" hardware failure is another contributor to AFW failure, which could be mitigated with the AFW cross-tie (SAMA 15).

Scenario "D" is initiated in the pressurizer power supply transformer/panel and results in failure of AFW "A", thermal barrier cooling, the division 1 sump suction path, SI pump "B", SX pump "A", charging pump "A", EDG 2A, and the normal high pressure recirc suction path, along with other failures. Similar to scenario "B", failure to refill the AFW "B" diesel fuel oil tank and other AFW "B" hardware failures are large contributors and the same SAMAs are applicable. In addition, RCP seal LOCAs are a significant contributor due to the fire induced failure of the "A" charging pump. The RCP seal LOCAs can be addressed by the installation of "no-leak" seals (SAMA 4).

The ignition sources themselves do not fail AFW and a potential means of mitigating this scenario would be to wrap the cables associated with AFW valves 2AF005A through D (SAMA 35).

U2: 11.4-0 (Scenarios E, B), Auxiliary Building General Area, Elevation 383

The larger contributor, fire scenario "E", is initiated in 480V MCC 232X1, which results in failure of SX pump 2B, SX unit 2 CC HX outlet, AFW pump 2B, charging pump 2B, RH pump 2B, SI pump 2B, EDG 2B, and others. Most of the failures are related to loss of the ignition source. In scenario "B", the ignition source is AFW pump 2A, which also fails charging pump "0", and the SX suction path for AFW.

In most scenario "E" cases, an additional SX hardware failure eliminates the last remaining heat sink, and core damage occurs. The AFW cross-tie would help mitigate these failures by providing a heat sink that is not dependent on the unit's SX system (SAMA 15). Seal LOCAs are also a contributor, which could be addressed by "no-leak" seals (SAMA 4). For scenario "B", the largest contributors to the conditional core damage probability are failures of the "B" AFW pump, including the failure to refill the diesel fuel oil tank and multiple pump hardware failures. Automating the refill function would reduce the contribution of these scenarios (SAMA 18). AFW "B" hardware failures could be mitigated with the AFW cross-tie (SAMA 15).

In both scenarios, the fire induced damage is primarily the result of the loss of the ignition source, so fire barriers would provide little benefit for this scenario. Because many of the fire induced failures identified above are the result of damage to the ignition source for the fire scenario, the means of preventing loss of the equipment is limited to enhancements that prevent the fire from developing. Incipient fire detectors are a potential means of accomplishing this goal; however, the reliability of incipient detectors to prevent fires has neither been established nor accepted in the industry, and this enhancement is not suggested as a SAMA.

U2: 18.12-0 (Scenario A), Lake Screen House

This scenario is a bounding fire that is based on the total initiating event frequency for the zone. The consequence of the fire is a loss of the diesel fire pump, which has a limited impact on the results. In general, improving the reliability of the AFW system would reduce the frequency of the fire scenario, which could be accomplished by completing the implementation of the AFW cross-tie (SAMA 15) or using AMSAC as a backup AFW start signal (SAMA 17). The diesel fire pump itself is primarily used to provide alternate lube oil cooling to the charging pumps for seal LOCA prevention, but for this fire scenario, seal LOCAs are less than a 1% contributor to the conditional core damage probability.

U2: 11.5-0 (Scenario R), Aux Building General Area, Elevation 401'

Scenario "R" is initiated in Unit 2 480V MCC 231X3, which fails multiple loads including, AFW 2A, the 2A SX pump, EDG 2A, SI pump 2A.

For scenario "R", the largest contributors to the conditional core damage probability are failures of the "B" AFW pump, including the failure to refill the diesel fuel oil tank and multiple pump hardware failures. Automating the refill function would reduce the contribution of these scenarios (SAMA 18). AFW "B" hardware failures could be mitigated with the AFW cross-tie (SAMA 15).

Larger contributors to the conditional core damage probability include operator failures to refill the "B" AFW fuel oil tank, align recirculation mode, and to stop the RHR pumps when they are running without CC cooling to the heat exchangers. SAMAs that could reduce the risk of these scenarios include automating the AFW diesel fuel oil refill function (SAMA 18), a procedure change to align CCW flow to the RH Heat Exchanges on RH pump start (SAMA 7), and automating the swap to recirculation mode (SAMA 30). Completing the AFW cross-tie would also reduce the contribution from AFW hardware failures (SAMA 15).

In this scenario, the fire induced damage is primarily the result of the loss of the ignition source, so fire barriers would provide little benefit for this scenario. Because many of the fire induced failures identified above are the result of damage to the ignition source for the fire scenario, the means of preventing loss of the equipment is limited to enhancements that prevent the fire from developing. Incipient fire detectors are a potential means of accomplishing this goal; however, the reliability of incipient detectors to prevent fires has neither been established nor accepted in the industry, and this enhancement is not suggested as a SAMA.

U2: 1-1 (Scenario A), Unit 1 Containment

In this "bounding" fire scenario, the fire induced failures are Unit 1 equipment and the fire is modeled as requiring a Unit 2 shutdown without the availability of untraced equipment, such as the main feedwater system. For these cases, improving the reliability of the AFW system would reduce the contribution from this fire scenario, which could be accomplished by completing the implementation of the AFW cross-tie (SAMA 15) or using AMSAC as a backup AFW start signal (SAMA 17).

U2: 11.6c-0 (Scenario A), Auxiliary building laundry room

This scenario is a bounding fire that is based on the total initiating event frequency for the zone, which in this zone is comprised of all transient initiators.

The consequences for Unit 2 are loss of the 4KV 241 bus and charging pump 2A.

The largest contributors to the consequential CDF for this scenario are failure to refill the AFW "B" fuel oil tank and the failure to start the standby SX pump.

SAMAs that could reduce the risk of these scenarios include automating the AFW diesel fuel oil refill function (SAMA 18) and installing an auto start function on the standby SX pump for loss of flow conditions (SAMA 3).

No practical SAMAs have been identified to prevent the transient fires in this fire zone and because the fire is a bounding fire, no specific information is available regarding fire propagation or ignition sources that would help identify effective equipment protection methods.

U2: 18.10E-2 (Scenarios B, D, C), System Auxiliary Transformers 242-1 and 242-2

These fire scenarios are in either, or both, SATs 242-1 and 242-2. The result is loss of the feed from the system auxiliary transformer (SAT) that is damaged in the fire.

Loss of the normal power feeds to the emergency buses increases the importance of emergency AC power and SBO coping capabilities. Implementing the DMS will help mitigate these fires by providing a long term means of SG makeup and primary side integrity/makeup (SAMA 11).

Because the fire induced failures identified above are the result of damage to the ignition source for the fire scenario, the means of preventing loss of the equipment is limited to enhancements that prevent the fire from developing. Incipient fire detectors are a potential means of accomplishing this goal; however, the reliability of incipient detectors to prevent fires has neither been established nor accepted in the industry, and this enhancement is not suggested as a SAMA.

U2: 18.10E-1 (Scenarios B, D, C), System Auxiliary Transformers 142-1 and 142-2

These fire scenarios are in either, or both, SATs 142-1 and 142-2. The result is loss of the feed from the SAT that is damaged in the fire. It has no direct impact on Unit 2 equipment apart from a degraded 4KV cross-tie capability.

Implementing the DMS will help mitigate any power cross-tie failures by providing a long term means of SG makeup and primary side integrity/makeup (SAMA 11).

Because the fire induced failures identified above are the result of damage to the ignition source for the fire scenario, the means of preventing loss of the equipment is limited to enhancements that prevent the fire from developing. Incipient fire detectors are a potential means of accomplishing this goal; however, the reliability of incipient detectors to prevent fires has neither been established nor accepted in the industry, and this enhancement is not suggested as a SAMA.

U2: 8.6-0 (Scenario A), Turbine Building Operating Floor

This fire has no direct impact on any equipment modeled in the PRA, but is assumed to result in a plant shutdown. SAMAs for the internal events model are applicable to these cases.

E.5.1.6.1.1 Fire SAMA Identification Summary

Based on a review of the Braidwood fire area results, eight (8) additional SAMAs have been identified for inclusion in the Phase 1 SAMA list:

- Protect RH, SI, and CVCS Cubicle Cooling Fan Cables in Fire Zone 11.3-0 (SAMA 27)
- Install Fire Barriers around MCC 132X4 (SAMA 28)
- Seal the Inverter 111 Panel and Install Fire Barriers to Protect Nearby Equipment (SAMA 29)
- Install Fire Barriers around MCCs 132X5 and 134X (SAMA 31)
- Install Fire Barriers around MCC 131X2 (SAMA 32)

- Unit 2 SAMA - Install Cable Wrap on the 141 to 241 4KV Cross-tie Cable in the Division 11 ESF Switchgear Room (SAMA 33)
- Unit 2 SAMA - Install Cable Wrap on the 141 to 241 4KV Cross-tie Cable in the Aux Building Elevation 426' of the General Area (SAMA 34)
- Unit 2 SAMA - Install Cable Wrap to Protect 2AF005A, B, C, and D in the Division 21 Containment Electrical Penetrations Area (SAMA 35)

F.5.1.6.2 Seismic Events

The IPEEE (ComEd 1997b) indicates that the EPRI seismic margins methodology was used to identify the minimal set of equipment required to safely shut the reactor down and to determine if that equipment is capable of surviving the Review Level Earthquake (RLE). The RLE, which is generally larger than the design basis earthquake, is a seismic event determined by a combination of the site's seismic hazard and seismic design basis that is intended to challenge the plant and identify the weak links for seismic events that are larger than the RLE. Equipment that is not capable of withstanding the RLE, which at Braidwood is a 0.3g event that results in a peak acceleration value of 0.636g at 8 Hz, is identified and required to be addressed. While methods exist for using this information to develop a figure of merit, it is not technically equivalent to a core damage frequency and was not performed as part of the Braidwood IPEEE.

It should also be noted that even in a seismic probabilistic risk assessment, the pedigree of information is not equivalent to what is used in the internal events models. Given that there is a limited amount of seismic response information available for nuclear power plants, analysis techniques developed to model the plant response often compensate by ingraining a conservative bias in their methodologies to prevent overestimating the capabilities of the plants. While seismic risk evaluations are helpful in the identification of potential plant weaknesses, the degree of uncertainty in the CDF and other results is likely significantly larger than for internal events. With these limitations in mind, the Braidwood IPEEE seismic results and history were reviewed in order to determine if there were any unresolved issues that could impact Braidwood risk. The issues of potential interest included:

- Unfinished plant enhancements that were determined to be required to ensure the equipment on the Safe Shutdown List would be capable of withstanding the RLE.
- Additional plant enhancements that were identified as a means of reducing plant risk, but were not implemented at the plant.

An effort was also made to use the results of the equipment and structural screening documentation to determine if any outlier issues there were screened in the IPEEE could impact seismic risk at Braidwood.

The conclusion of the seismic analysis for Braidwood was that the plant HCLPF is greater than 0.30g peak ground acceleration (PGA) and no programmatic issues were identified. However, Table 3.3 of the IPEEE documents the "outliers" that were identified as part of the seismic capacity assessments. These are generally items with potential seismically induced interaction issues for which it was difficult to calculate a High Confidence of Low Probability of Failure value. Those that were not clearly identified as resolved in the IPEEE are identified below in conjunction with their dispositions for the SAMA analysis.

Summary of Seismic Outlier Resolutions

Equipment ID #	Outlier Finding	SAMA Disposition[1]
1(2)CV112E	Valve operator is in contact with adjacent platform steel/grating, which poses an impact hazard.	Evaluations have determined that the affected piping systems and valve are adequate with the reduced clearance. No SAMAs are considered to be required.
1(2)AP27E	Seismic interaction concern. Not bolted to adjacent MCC 1(2)AP47E and may impact MCC during seismic event.	MCCs are bolted to adjacent MCCs. No SAMAs are considered to be required.
2AP38E	Interaction hazard due to MCC not bolted to adjacent cubicle in line-up.	Cabinet is bolted to adjacent cabinet. No SAMAs are considered to be required.
1(2)DC03E 1(2)DC05E	Adjacent cabinets not bolted together. The calculated spectral displacement of the cabinets exceeds the available clearance.	Interactions were evaluated that addressed the loads for panels and concluded that they were acceptable when linked together. Plant records indicate these cabinets are now linked together (EC42705, EC42706). No SAMAs are considered to be required.
2DC04E 2DC06E	Adjacent cabinets not bolted together. The calculated spectral displacement of the cabinets exceeds the available clearance.	Interactions were evaluated that addressed the loads for panels and concluded that they were acceptable when linked together. Plant records indicate these cabinets are now linked together (EC42706). No SAMAs are considered to be required.

[1] Plant resolutions are based on the information provided in the plant seismic walkdown reports (Exelon 2012a, Exelon 2012b) unless otherwise noted.

Summary of Seismic Outlier Resolutions

Equipment ID #	Outlier Finding	SAMA Disposition[1]
1RD05E 2RD05E	Seismic interaction concern. Not bolted to adjacent 1(2)RD03E. May impact during seismic event.	Interactions were evaluated that addressed the loads for panels and concluded that they were acceptable when linked together. Plant records indicate these cabinets are now linked together (EC42706). No SAMAs are considered to be required.
2SX112B	Outlier due to power cable pull box in contact with overhead steel.	Condulet and solenoid valve were adjusted in field to provide additional clearances. No SAMAs are considered to be required.
1TE0674	An adjacent 12” diameter line is only 1” away from the temperature element. The pipe is hung on a flexible 8’ long rod trapeze hanger (no lateral supports) at 10’. The calculated spectral displacement of the pipe in question exceeds the 1” clearance.	This item was closed by ECR 362265 and WO 99006174. No SAMAs are considered to be required.
1(2)SX178	Outlier due to seismic interaction (impact) potential with adjacent structural member.	Evaluated and found to be acceptable. No SAMAs are considered to be required.

Summary of Seismic Outlier Resolutions

Equipment ID #	Outlier Finding	SAMA Disposition[1]
0PM01J 0PM02J 1PM01J 1PM04J 1PM05J 1PM06J 1PM07J 1PM11J 1PM12J 2PM01J 2PM04J 2PM05J 2PM06J 2PM07J 2PM11J 2PM12J	Unsecured aluminum diffusers in suspended ceiling pose a personnel hazard to operators if they are dislodged due to seismic motion.	Analysis was performed which evaluated the capacity of the diffusers for withstanding a seismic event of a magnitude required by the IPEEE without an adverse effect. Conclusively, the ceiling diffusers are capable of withstanding a seismic event of a magnitude required by the IPEEE without adverse effect. No SAMAs are considered to be required.
1(2)PL07J 1(2)PL08J	Interaction hazard due to a hearing booth (like a portable phone booth on legs) adjacent to the panels, which, even though item is chained off, can still roll into panel or tip over into panel.	Hearing booths were relocated and chained to eliminate potential seismic interaction. No SAMAs are considered to be required.

Summary of Seismic Outlier Resolutions

Equipment ID #	Outlier Finding	SAMA Disposition[1]
1(2)PA01J 1(2)PA02J 1(2)PA03J 1(2)PA04J 1(2)PA06J 1(2)PA07J 1(2)PA08J 1(2)PA09J 1(2)PA10J 1(2)PA11J 1(2)PA12J 1(2)PA13J 1(2)PA14J 1(2)PA27J 1(2)PA28J 1(2)PA33J 1(2)PA34J 1(2)PA51J 1(2)PA52J	Adjacent cabinets not bolted together.	Interactions were evaluated that addressed the loads for panels and concluded that they were acceptable when linked together. Plant records indicate these cabinets are now linked together (EC42705, EC42706). No SAMAs are considered to be required.

F.5.1.6.3 High Winds and Tornadoes

The approach taken to analyze the high wind, flood, transportation and nearby facility, and "other" external event risk in the Braidwood IPEEE was to implement a progressive screening approach. The first three steps included 1) a review of Braidwood specific hazard data and licensing basis, 2) identification of significant changes since Operating License issuance, and 3) verification that the Braidwood design met the 1981 Standard Review Plan (SRP) criteria (in NUREG-1407, the 1975 SRP criteria are specified, but the 1981 SRP was determined to be equivalent for use as an IPEEE screening tool). An affirmative determination that the 1981 SRP screening criteria were met resulted in the screening of the hazard on the basis that conformance to the SRP met the IPEEE screening criterion.

For the SAMA analysis, this process is considered adequate for screening events that do not pose a credible threat to plant operations. However, any issues that could impact plant safety are reconsidered to determine if the development of a SAMA is appropriate to address the risk. For Braidwood, no high wind or tornado vulnerabilities were identified in the IPEEE and there are no relevant potential plant enhancements.

In conclusion, no high wind or tornado related SAMAs are required for Braidwood.

F.5.1.6.4 External Floods

For external flooding events, Braidwood Station was determined to meet the NRC's SRP for external flooding and these types of events were screened from further review. The IPEEE indicates that roof loading and grade level effects were considered related to Probable Maximum Precipitation (PMP) or Probable Maximum Flooding (PMF) events.

For PMP events, the IPEEE indicated that even under the worst postulated conditions, the roof design loads were not exceeded.

Flooding as a result of PMP or PMF effects was determined to not challenge the plant. Maximum Flood levels were determined to peak at 571 feet mean sea level while plant grade is 600 feet mean sea level. For PMP events with short term pooling of water at elevations above the 600 feet plant grade, plant structures were found to be protected by curbed entries that would prevent water incursion.

For Braidwood, no external flooding vulnerabilities were identified in the IPEEE and there are no relevant potential plant enhancements.

F.5.1.6.5 Transportation and Nearby Facility Accidents

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

- Ground Transportation Accidents
- Accidents at Nearby Facilities
- Aircraft Accidents

Both road and rail shipments in the area of the plant were evaluated by the NRC using the criteria in the SRP. No conditions were identified that posed a significant risk to the site and these types of events were screened from further consideration in the IPEEE. No SAMAs, therefore, are required to address these types of events.

The potential for nearby facility accidents was reviewed in the IPEEE and it was determined that of the facilities located within 10 miles of the plant, none posed a significant risk to the plant. The U.S. Army Joliet Arsenal was considered to potentially pose the most significant risk of the nearby facilities, but the arsenal has ceased activities. No conditions were identified that posed a significant risk to the site and events at nearby facilities were screened from further consideration in the IPEEE. No SAMAs, therefore, are required to address these types of events.

It is recognized that the types of credible threats to nuclear facilities by aircraft have changed since the time the IPEEE was published. While this is true, efforts are underway within the industry to address this issue in conjunction with other forms of sabotage. Based on the fact that this topic is currently being analyzed in another forum and due to the complexity of the issue, intentional aircraft impact events are considered to be out of the scope of the SAMA analysis. Accidental aircraft impact was reviewed in the IPEEE and it was determined that no airports are located within 10 miles of the site and that only two low altitude flyways pass within the same radius. The conclusion in the IPEEE was that the SRP acceptance criteria were met and accidental aircraft impact posed no significant threat to plant operations. No SAMAs, therefore, are required to address these types of events.

F.5.2 PHASE 1 SCREENING PROCESS

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

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

- Applicability to the Plant: If a proposed SAMA does not apply to the Braidwood design, it is not retained. Similarly, any SAMAs that have already been implemented by Exelon or achieve results that Exelon has achieved by other means can be screened as they are not applicable to the current plant design. These criteria are not often explicitly used in the Phase I analysis because the SAMA identification methodology generally excludes such SAMAs; however, they are listed as a possible screening method given that there may be circumstances in which a SAMA would be included in the list even if it is not relevant to the site. An example may be the inclusion of a high profile SAMA that is well known in the industry, but not applicable to the specific site design. Such a SAMA may be included for documentation purposes. Another example may be an unimplemented SAMA from the IPE that has been superseded by another plant enhancement.

- Implementation Cost Greater than Screening Cost: If the estimated cost of implementation is greater than the modified MACR (refer to Section F.4.6), the SAMA cannot be cost beneficial and is screened from further analysis.

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

F.6 PHASE 2 SAMA ANALYSIS

The SAMA candidates identified as part of the Phase 2 analysis are listed in Table F.6-1. The base PRA model was manipulated to simulate implementation of each of the proposed SAMAs and then quantified to determine the risk benefit. Truncation values and binning cutoffs are the same as used in the base PRA model (CDF, LERF, Seismic and Fire), including Level 2 endstates.

In general, in order to maximize the potential risk benefit due to implementation of each of the SAMAs, the failure probabilities assigned to new basic events, such as human error probabilities (HEPs), were optimistically chosen so as not to inadvertently screen out any potential cost-beneficial SAMAs. Also, any new model logic that was added to the PRA model in order to simulate SAMA implementation was also simplified and optimistically configured to achieve the same effect.

Determining whether or not any given Phase 2 SAMA is potentially cost beneficial involved calculating what is known as the averted cost-risk, which was obtained by a multi-step process that includes the use of the baseline MACR as well as the internal events PRA results and a multiplier to account for external events contributions.

- The averted cost-risk is the difference between the baseline MACR and the MACR for the configuration in which the SAMA has been implemented ($MACR_{SAMA}$). The $MACR_{SAMA}$ is comprised of the internal events contribution and the external events contribution.
  - The internal events portion of the $MACR_{SAMA}$ is calculated in the same manner as for the baseline MACR using the CDF, Level 2 PRA results, etc., as shown in Sections F.4.1 through F.4.6.1.
  - The contribution from the external events to the $MACR_{SAMA}$ is accounted for by multiplying the internal events $MACR_{SAMA}$ by the External Events Multiplier (refer to section F.4.6.2).

For some SAMAs identified by the Fire results review, the internal events PRA does not provide a means of modeling the impact of the SAMA. In these cases, the averted cost-risk is estimated using fire model insights and information from the internal events MACR calculation. The averted cost-risk is obtained by multiplying the internal events contribution to the MACR by the ratio of the CDF eliminated by the SAMA to the base internal events CDF.

- The assumption is that the fire CDF is proportional to the internal events MACR. For example, if the SAMA is assumed to eliminate the entire CDF associated with Unit 1 fire zone 1-1, the averted cost risk would be (7.02E-06 / 3.57E-05 * $16,576,000 = $3,259,482)

Finally, a SAMA is determined to be potentially cost beneficial if its net value is positive. The net value is determined by the following equation:

Net Value = averted cost-risk – cost of implementation

The implementation costs used in the Phase 1 and 2 analyses consist of industry estimates, Braidwood specific estimates, or in some cases, combinations of these two sources. It should be noted that Braidwood specific implementation costs do include contingency costs for unforeseen difficulties, but do not account for any replacement power costs that may be incurred due to consequential shutdown time unless specifically noted. Table F.5-3 provides implementation costs for each Phase 1 and Phase 2 SAMA.

The following sections describe the cost-benefit analysis that was used for each of the Phase 2 SAMA candidates.

It should be noted that apart from fire considerations, Braidwood units 1 and 2 are essentially identical in design and operation. The differences associated with fire related issues have been addressed by performing unit specific fire SAMA identification tasks and by using unit specific risk insights for quantification, when relevant. SAMAs developed to prevent or mitigate fire damage or propagation in a specific fire scenario required a unit specific quantification using the method described above. Unit specific fire SAMAs are applicable only to the unit for which they were derived. SAMAs identified to mitigate the impact of fire damage (e.g., SAMA 11 – Implement the DMS) were all also applicable to the internal events model and the External Events Multiplier was used to account for any fire related benefits for those types of SAMAs.

For all non-fire based SAMAs, the unit 1 PRA model was employed to evaluate the risk benefits and averted costs for each of the SAMAs, and was viewed as also being applicable to Unit 2. That is, if a particular SAMA proves potentially cost beneficial for Unit 1, it will likewise be potentially cost beneficial for Unit 2.

F.6.1 SAMA 1: DIESEL DRIVEN SX PUMP

In order to mitigate CCF failure of the SX pumps, a diesel driven pump could be installed in a flood safe location with suction from the normal service water (WS) forebay that includes a suction strainer of an alternate design that is accessible for manual cleaning (in place of the pump discharge strainers). Auto start capability would be required to increase the benefit of the SAMA, but water level interlocks for critical rooms (e.g., SX pump rooms, Aux Building sump) may be required to prevent auto start in SX flooding evolutions.

Assumptions:

The diesel driven SX pump is diverse from the existing pumps such that it can be excluded from SX pump common cause failure groups.

The diesel driven SX pump suction strainer is diverse from the discharge strainers on the existing SX pumps such that it can be excluded from the SX strainer common cause failure groups.

The diesel driven SX pump uses the process fluid to cool the engine and does not require cooling support.

The diesel driven SX pump has auto start capability on low SX system flow.

A pump is required for each unit to meet flow requirements for some of the largest contributing accident sequences (common cause failure of SX for both units).

The diesel driven SX pump can be treated as a lumped event with a failure probability of 1E-2.

It is assumed that the diesel driven SX discharge line will tie into the SX piping in the same functional position as the "B" SX pump between the _SX034 and _SX005 valves.

PRA Model Changes to Model SAMA:

The fault tree was updated to incorporate the diesel driven SX pump under the existing SX system logic.

Model Change(s):

The following modeling changes were made:

- New event 1SAMA1: SAMA 1 DIESEL DRIVEN SX PUMP FAILS; 1.00E-02.
- Under existing gate 0SX-PUMPS-ALL: Added NEW event 1SAMA1.
- Under existing gate 1RCFC-1AC-SX2: Added NEW event 1SAMA1.
- Under existing gate 1RCFC-1BD-SX2: Added NEW event 1SAMA1.
- Under existing gate 1SX-HX0-PUMPAB: Added NEW event 1SAMA1.
- Under existing gate 1SX-UNIT1-HW: Added NEW event 1SAMA1.
- Under existing gate 1SX-HX0-TRB-ONLY: Added NEW event 1SAMA1.
- Under existing gate 1SX-TRAIN-B-ONLY: Added NEW event 1SAMA1.

Results of SAMA Quantification:

Implementation of this SAMA yielded a moderate reduction in internal CDF and similar reductions in Dose-Risk and Offsite Economic Cost-Risk. The results are summarized in the following table:

	Internal CDF	Dose-Risk	OECR
Base Value	3.57E-05	113.76	$809,628
SAMA Value	1.62E-05	25.27	$105,108
Percent Change	54.6%	77.8%	87.0%

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

Release Category	$Freq._{BASE}$	$Freq._{SAMA}$	$Dose\text{-}Risk_{BASE}$	$Dose\text{-}Risk_{SAMA}$	$OECR_{BASE}$	$OECR_{SAMA}$
INTACT	1.34E-05	1.36E-05	3.32E-01	3.37E-01	$300	$305
SERF-TISGTR-HLF	8.12E-09	8.19E-09	3.01E-02	3.04E-02	$229	$231
SERF-SGTR-AFW-SC	1.48E-06	1.48E-06	5.70E+00	5.70E+00	$24,716	$24,716
LATE-BMMT-AFW	6.07E-07	1.23E-06	4.03E-02	8.17E-02	$31	$62
LATE-BMMT-NOAFW	9.95E-08	1.38E-07	1.90E-02	2.64E-02	$31	$43
LATE-CHR-AFW	1.37E-05	5.58E-07	2.14E+01	8.70E-01	$45,210	$1,841
LATE-CHR-NOAFW	7.51E-06	1.17E-07	6.59E+01	1.03E+00	$642,105	$10,004
LERF-ISLOCA	3.40E-07	3.40E-07	1.55E+01	1.55E+01	$54,400	$54,400
LERF-CI	3.63E-07	1.28E-07	1.18E+00	4.16E-01	$3,775	$1,331
LERF-CFE	3.14E-08	1.32E-08	2.92E-01	1.23E-01	$2,003	$842
LERF-SGTR-AFW	5.92E-08	5.92E-08	5.19E-01	5.19E-01	$4,422	$4,422
LERF-SGTR-NOAFW	9.64E-10	7.65E-10	2.98E-03	2.36E-03	$24	$19
LERF-ISGTR	2.57E-07	5.47E-08	2.80E+00	5.96E-01	$32,382	$6,892
Total	**3.79E-05**	**1.77E-05**	**1.14E+02**	**2.53E+01**	**$809,628**	**$105,108**

Applying the process described in Section F.4 yields an internal events cost-risk of $2,784,263. After accounting for “round up” of the base internal events cost-risk, this value is $2,784,520. The external events contributions are accounted for by multiplying this value by 2.8:

$$\text{Total Cost-Risk}_{SAMA} = \$2,784,520 * 2.8 = \$7,796,656$$

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

SAMA 1 Averted Cost-Risk

Unit	Base Case Cost-Risk	Revised Cost-Risk	Averted Cost-Risk
Braidwood Unit 1	$46,412,800	$7,796,656	$38,616,144

Based on a $46,431,000 cost of implementation for Braidwood, the net value for this SAMA is -$7,814,856 ($38,616,144 - $46,431,000), which indicates this SAMA is not cost beneficial.

F.6.2 SAMA 2: REPLACE THE POSITIVE DISPLACEMENT PUMP WITH A SELF COOLED, AUTO START PUMP

Loss of SX requires swap of the charging pump suction source to the RWST as well as alignment of an alternate lube oil cooling source to maintain RCP seal injection. Replacing the positive displacement pump with a self-cooled pump with the capability to auto start on loss of charging and SX flow would provide a means of seal cooling on loss of the normal pumps. Providing an automatic transfer switch to allow power from either division would enhance the SAMA's capability.

Assumptions:

The seal injection pump is assumed to have a failure probability of 1E-3. Division 1 and division 2 emergency 480V AC power are assumed to be available to the new seal injection pump with an automatic transfer switch that is 100% reliable.

PRA Model Changes to Model SAMA:

The fault tree was updated to incorporate the self-cooled pump and power supplies under the existing seal injection logic.

Model Change(s):

The following modeling changes were made:

- New OR gate 1SAMA2-SEAL-INJ: Include new event 1SAMA2 and new gate 1SAMA2-POWER.
- New AND gate 1SAMA2-POWER: Include existing gates 1AP-BUS131X4 and 1AP-BUS132X4.
- New event 1SAMA2: SAMA 2 SEAL INJECTION PUMP FAILS; 1.00E-03.
- Under existing gate 1CSLOCA: Added NEW gate 1SAMA2-SEAL-INJ.

- Under existing gate 1CSLOCA-IE: Added NEW gate 1SAMA2-SEAL-INJ.
- Under existing gate 1LOSC-141: Added NEW gate 1SAMA2-SEAL-INJ.
- Under existing gate 1LOSC-142: Added NEW gate 1SAMA2-SEAL-INJ.
- Under existing gate 1LOSC-LOOP: Added NEW gate 1SAMA2-SEAL-INJ.
- Under existing gate 1RCP-SEALLOCA-SLB: Added NEW gate 1SAMA2-SEAL-INJ.

Results of SAMA Quantification:

Implementation of this SAMA yielded a moderate reduction in internal CDF and similar reductions in Dose-Risk and Offsite Economic Cost-Risk. The results are summarized in the following table:

	Internal CDF	Dose-Risk	OECR
Base Value	3.57E-05	113.76	$809,628
SAMA Value	1.93E-05	92.15	$762,800
Percent Change	45.9%	19.0%	5.8%

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

Release Category	$Freq._{BASE}$	$Freq._{SAMA}$	$Dose\text{-}Risk_{BASE}$	$Dose\text{-}Risk_{SAMA}$	$OECR_{BASE}$	$OECR_{SAMA}$
INTACT	1.34E-05	1.00E-05	3.32E-01	2.48E-01	$300	$224
SERF-TISGTR-HLF	8.12E-09	8.12E-09	3.01E-02	3.01E-02	$229	$229
SERF-SGTR-AFW-SC	1.48E-06	1.48E-06	5.70E+00	5.70E+00	$24,716	$24,716
LATE-BMMT-AFW	6.07E-07	4.09E-07	4.03E-02	2.72E-02	$31	$21
LATE-BMMT-NOAFW	9.95E-08	9.95E-08	1.90E-02	1.90E-02	$31	$31
LATE-CHR-AFW	1.37E-05	3.29E-07	2.14E+01	5.13E-01	$45,210	$1,086
LATE-CHR-NOAFW	7.51E-06	7.51E-06	6.59E+01	6.59E+01	$642,105	$642,105
LERF-ISLOCA	3.40E-07	3.40E-07	1.55E+01	1.55E+01	$54,400	$54,400
LERF-CI	3.63E-07	2.07E-07	1.18E+00	6.73E-01	$3,775	$2,153
LERF-CFE	3.14E-08	1.58E-08	2.92E-01	1.47E-01	$2,003	$1,008
LERF-SGTR-AFW	5.92E-08	5.92E-08	5.19E-01	5.19E-01	$4,422	$4,422
LERF-SGTR-NOAFW	9.64E-10	9.64E-10	2.98E-03	2.98E-03	$24	$24

Release Category	$Freq._{BASE}$	$Freq._{SAMA}$	$Dose\text{-}Risk_{BASE}$	$Dose\text{-}Risk_{SAMA}$	$OECR_{BASE}$	$OECR_{SAMA}$
LERF-ISGTR	2.57E-07	2.57E-07	2.80E+00	2.80E+00	$32,382	$32,382
Total	3.79E-05	2.07E-05	1.14E+02	9.22E+01	$809,628	$762,800

Applying the process described in Section F.4 yields an internal events cost-risk of $14,772,515. After accounting for "round up" of the base internal events cost-risk, this value is $14,772,772. The external events contributions are accounted for by multiplying this value by 2.8:

$$\text{Total Cost-Risk}_{SAMA} = \$14,772,772 * 2.8 = \$41,363,762$$

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

SAMA 2 Averted Cost-Risk

Unit	Base Case Cost-Risk	Revised Cost-Risk	Averted Cost-Risk
Braidwood Unit 1	$46,412,800	$41,363,762	$5,049,038

Based on a $5,751,110 cost of implementation for Braidwood, the net value for this SAMA is -$702,072 ($5,049,038 - $5,751,110), which indicates this SAMA is not cost beneficial.

F.6.3 SAMA 3: AUTO START OF STANDBY SX PUMP

The SX system includes logic that starts the standby SX pump for initiating events that generate SI or bus under-voltage signals, but for events without these signals, manual start of the standby SX pump is required when the running pump fails.

Automating the start of the standby SX pump would help reduce the reliance of operators to maintain cooling to critical loads. Use of flooding interlocks could be used to prevent auto actuation in flooding scenarios.

Assumptions:

It is assumed that the auto start logic of the standby SX pump can represented by a lumped event accounting for hardware and support system dependencies. The failure probability of the event (1SX-AUTOSTART) is assumed to be 1E-04.

The new autostart function also serves as a backup to the SI and under-voltage start signals.

PRA Model Changes to Model SAMA:

The standby SX pump start logic has been modified to include the auto start event (1SX-AUTOSTART) such that a failure of the SX pump to start requires failure of both the automated start function and the manual operator action.

Model Change(s):

Event 1SX-AUTOSTART has been included under the following gates:

- 1SX-PUMP-1A-SIG1: SX PUMP IS NOT STARTED MANUALLY FOR OTHER INITIATORS
- 1SX-PM1A-DG-ACT: SX PUMP 1A FTS VIA SIGNAL FAULT (DG SUPPORT- IELOP CAN BE PRESUMD; DC
- 1SX-PM1A-LOOP: SX PUMP 1A IS NOT ACTIUATED FOR LOOP IE
- 1SX-PM1B-DG-ACTSX PUMP 1B FTS VIA SIGNAL FAULT (DG SUPPORT- IELOP CAN BE PRESUMD; DC
- 1SX-PM1B-LOOP: SX PUMP 1A IS NOT ACTIUATED FOR LOOP IE
- 1SX-PUMP-1B-SIG1: SX PUMP IS NOT STARTED MANUALLY FOR OTHER INITIATORS

Results of SAMA Quantification:

Implementation of this SAMA yielded a moderate reduction in internal CDF and similar reductions in Dose-Risk and Offsite Economic Cost-Risk. The results are summarized in the following table:

	Internal CDF	Dose-Risk	OECR
Base Value	3.57E-05	113.76	$809,628
SAMA Value	2.86E-05	99.93	$757,488
Percent Change	19.9%	12.2%	6.4%

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

Release Category	$Freq._{BASE}$	$Freq._{SAMA}$	Dose-$Risk_{BASE}$	Dose-$Risk_{SAMA}$	$OECR_{BASE}$	$OECR_{SAMA}$
INTACT	1.34E-05	1.34E-05	3.32E-01	3.32E-01	$300	$300
SERF-TISGTR-HLF	8.12E-09	8.12E-09	3.01E-02	3.01E-02	$229	$229

Release Category	Freq.$_{BASE}$	Freq.$_{SAMA}$	Dose-Risk$_{BASE}$	Dose-Risk$_{SAMA}$	OECR$_{BASE}$	OECR$_{SAMA}$
SERF-SGTR-AFW-SC	1.48E-06	1.48E-06	5.70E+00	5.71E+00	$24,716	$24,756
LATE-BMMT-AFW	6.07E-07	6.07E-07	4.03E-02	4.03E-02	$31	$31
LATE-BMMT-NOAFW	9.95E-08	9.95E-08	1.90E-02	1.90E-02	$31	$31
LATE-CHR-AFW	1.37E-05	6.88E-06	2.14E+01	1.07E+01	$45,210	$22,709
LATE-CHR-NOAFW	7.51E-06	7.19E-06	6.59E+01	6.31E+01	$642,105	$614,634
LERF-ISLOCA	3.40E-07	3.40E-07	1.55E+01	1.55E+01	$54,400	$54,437
LERF-CI	3.63E-07	2.91E-07	1.18E+00	9.44E-01	$3,775	$3,022
LERF-CFE	3.14E-08	2.47E-08	2.92E-01	2.30E-01	$2,003	$1,577
LERF-SGTR-AFW	5.92E-08	5.92E-08	5.19E-01	5.18E-01	$4,422	$4,421
LERF-SGTR-NOAFW	9.64E-10	9.64E-10	2.98E-03	2.98E-03	$24	$24
LERF-ISGTR	2.57E-07	2.49E-07	2.80E+00	2.71E+00	$32,382	$31,319
Total	3.79E-05	3.06E-05	1.14E+02	9.99E+01	$809,628	$757,488

Applying the process described in Section F.4 yields an internal events cost-risk of $15,181,261. After accounting for "round up" of the base internal events cost-risk, this value is $15,181,518. The external events contributions are accounted for by multiplying this value by 2.8:

$$\text{Total Cost-Risk}_{SAMA} = \$15,181,518 * 2.8 = \$42,508,250$$

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

SAMA 3 Averted Cost-Risk			
Unit	**Base Case Cost-Risk**	**Revised Cost-Risk**	**Averted Cost-Risk**
Braidwood Unit 1	$46,412,800	$42,508,250	$3,904,550

Based on a $1,130,300 cost of implementation for Braidwood, the net value for this SAMA is $2,774,250 ($3,904,550 - $1,130,300), which indicates this SAMA is potentially cost beneficial.

F.6.4 SAMA 4: INSTALL "NO LEAK" RCP SEALS

For loss of RCP seal cooling scenarios, a passive means of reducing the probability of an RCP seal LOCA is to replace the existing pump seals with "no leak" seals (e.g., Westinghouse "shield" seals) that are less likely to fail on loss of cooling.

Assumptions:

The “no-leak” seal capabilities are assumed to be represented by a lower RCP seal LOCA probability. The “no leak” seals are assumed to reduce the seal LOCA probability by a factor of 1000.

PRA Model Changes to Model SAMA:

The impact of implementing this SAMA has been estimated by modifying the base model cutset file. Using the cutset editor, the deleted flag “FLAG-SEAL-LOCA” is restored to the cutsets and assigned a value of 1E-3. Because the cutsets already include events that represent seal LOCA probabilities that are less than 1.0, this process ultimately reduces the probability that a seal LOCA occurs to less than the assumed value of 1E-3, but it conservatively shows an increased averted cost-risk for the SAMA.

Results of SAMA Quantification:

Implementation of this SAMA yielded a moderate reduction in internal CDF and similar reductions in Dose-Risk and Offsite Economic Cost-Risk. The results are summarized in the following table:

	Internal CDF	**Dose-Risk**	**OECR**
Base Value	3.57E-05	113.76	$809,628
SAMA Value	1.89E-05	90.69	$752,075
Percent Change	47.1%	20.3%	7.1%

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

Release Category	$Freq._{BASE}$	$Freq._{SAMA}$	$Dose\text{-}Risk_{BASE}$	$Dose\text{-}Risk_{SAMA}$	$OECR_{BASE}$	$OECR_{SAMA}$
INTACT	1.34E-05	9.86E-06	3.32E-01	2.45E-01	$300	$221
SERF-TISGTR-HLF	8.12E-09	8.12E-09	3.01E-02	3.01E-02	$229	$229
SERF-SGTR-AFW-SC	1.48E-06	1.48E-06	5.70E+00	5.71E+00	$24,716	$24,756
LATE-BMMT-AFW	6.07E-07	4.04E-07	4.03E-02	2.68E-02	$31	$21
LATE-BMMT-NOAFW	9.95E-08	9.94E-08	1.90E-02	1.90E-02	$31	$31
LATE-CHR-AFW	1.37E-05	2.38E-08	2.14E+01	3.71E-02	$45,210	$79
LATE-CHR-NOAFW	7.51E-06	7.40E-06	6.59E+01	6.50E+01	$642,105	$632,700
LERF-ISLOCA	3.40E-07	3.40E-07	1.55E+01	1.55E+01	$54,400	$54,437
LERF-CI	3.63E-07	2.07E-07	1.18E+00	6.73E-01	$3,775	$2,153
LERF-CFE	3.14E-08	1.57E-08	2.92E-01	1.46E-01	$2,003	$1,002
LERF-SGTR-AFW	5.92E-08	5.92E-08	5.19E-01	5.18E-01	$4,422	$4,421
LERF-SGTR-NOAFW	9.64E-10	9.64E-10	2.98E-03	2.98E-03	$24	$24
LERF-ISGTR	2.57E-07	2.54E-07	2.80E+00	2.77E+00	$32,382	$32,004
Total	3.79E-05	2.02E-05	1.14E+02	9.07E+01	$809,628	$752,075

Applying the process described in Section F.4 yields an internal events cost-risk of $14,556,364. After accounting for “round up” of the base internal events cost-risk, this value is $14,556,621. The external events contributions are accounted for by multiplying this value by 2.8:

$$\text{Total Cost-Risk}_{SAMA} = \$14,556,621 * 2.8 = \$40,758,539$$

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

SAMA 4 Averted Cost-Risk

Unit	Base Case Cost-Risk	Revised Cost-Risk	Averted Cost-Risk
Braidwood Unit 1	$46,412,800	$40,758,539	$5,654,261

Based on a $12,230,000 cost of implementation for Braidwood, the net value for this SAMA is -$6,575,739 ($5,654,261 - $12,230,000), which indicates this SAMA is not cost beneficial.

F.6.5 SAMA 5: MODIFY THE STARTUP FEEDWATER PUMP TO START USING THE AMSAC SG LOW-LOW-LOW LEVEL SIGNAL TO MITIGATE AFW FAILURE

For accident sequences in which main feedwater has tripped and AFW has failed to start, it is necessary to manually restart the FW system for continued SG makeup. By modifying the startup feedwater pump to auto start and align on low steam generator level, the need for operator intervention after AFW failure is essentially eliminated. Use of the AMSAC low-low-low SG level signal is an additional benefit that mitigates start signal failures.

Assumptions:

The auto start logic is only applicable to the startup FW pump, but to simplify the modeling, the auto start logic is also assumed to be capable of starting the main FW pump. This conservatively increases the averted cost-risk for this SAMA.

PRA Model Changes to Model SAMA:

The startup FW pump start logic has been modified to include the auto start event (1SUFW-AUTOSTART) such that a failure of the FW pumps to start requires failure of both the automated start function and the manual operator action.

Model Change(s):

The following modeling changes were made:

- Under gates 1FWR-TRANS and 1ALTFW-SLOCA: Added new AND gate 1FW-FWR-START. Deleted 1FW-FWR-OA
- New AND gate 1FW-FWR-START: Included existing gate 1FW-FWR-OA and new event 1SUFW-AUTOSTART.
- New event 1SUFW-AUTOSTART: AUTO START LOGIC FOR ALT FW FUNCTION. Failure prob. = 1.00E-04
- Under gate 1ALTFW-SGTR: Added new AND gate 1FW-FWR-START-SGTR. Deleted 1FW-FWR-OA-SGTR.

- New AND gate 1FW-FWR-START-SGTR: Included existing gate 1FW-FWR-OA-SGTR and new event 1SUFW-AUTOSTART.

Results of SAMA Quantification:

Implementation of this SAMA yielded a moderate reduction in internal CDF and similar reductions in Dose-Risk and Offsite Economic Cost-Risk. The results are summarized in the following table:

	Internal CDF	**Dose-Risk**	**OECR**
Base Value	3.57E-05	113.76	$809,628
SAMA Value	3.17E-05	81.08	$490,244
Percent Change	11.2%	28.7%	39.4%

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

Release Category	**$\text{Freq.}_{\text{BASE}}$**	**$\text{Freq.}_{\text{SAMA}}$**	**$\text{Dose-Risk}_{\text{BASE}}$**	**$\text{Dose-Risk}_{\text{SAMA}}$**	**$\text{OECR}_{\text{BASE}}$**	**$\text{OECR}_{\text{SAMA}}$**
INTACT	1.34E-05	1.30E-05	3.32E-01	3.22E-01	$300	$291
SERF-TISGTR-HLF	8.12E-09	6.90E-09	3.01E-02	2.56E-02	$229	$195
SERF-SGTR-AFW-SC	1.48E-06	1.48E-06	5.70E+00	5.70E+00	$24,716	$24,716
LATE-BMMT-AFW	6.07E-07	6.07E-07	4.03E-02	4.03E-02	$31	$31
LATE-BMMT-NOAFW	9.95E-08	7.59E-08	1.90E-02	1.45E-02	$31	$24
LATE-CHR-AFW	1.37E-05	1.37E-05	2.14E+01	2.14E+01	$45,210	$45,210
LATE-CHR-NOAFW	7.51E-06	3.95E-06	6.59E+01	3.47E+01	$642,105	$337,725
LERF-ISLOCA	3.40E-07	3.40E-07	1.55E+01	1.55E+01	$54,400	$54,400
LERF-CI	3.63E-07	3.23E-07	1.18E+00	1.05E+00	$3,775	$3,359
LERF-CFE	3.14E-08	2.70E-08	2.92E-01	2.51E-01	$2,003	$1,723
LERF-SGTR-AFW	5.92E-08	5.92E-08	5.19E-01	5.19E-01	$4,422	$4,422
LERF-SGTR-NOAFW	9.64E-10	1.99E-10	2.98E-03	6.15E-04	$24	$5
LERF-ISGTR	2.57E-07	1.44E-07	2.80E+00	1.57E+00	$32,382	$18,144
Total	3.79E-05	3.37E-05	1.14E+02	8.11E+01	$809,628	$490,244

Applying the process described in Section F.4 yields an internal events cost-risk of $10,679,810. After accounting for "round up" of the base internal events cost-risk, this value is $10,680,067. The external events contributions are accounted for by multiplying this value by 2.8:

$$\text{Total Cost-Risk}_{SAMA} = \$10,680,067 * 2.8 = \$29,904,188$$

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

SAMA 5 Averted Cost-Risk

Unit	Base Case Cost-Risk	Revised Cost-Risk	Averted Cost-Risk
Braidwood Unit 1	$46,412,800	$29,904,188	$16,508,612

Based on a $657,200 cost of implementation for Braidwood, the net value for this SAMA is $15,851,412 ($16,508,612 - $657,200), which indicates this SAMA is potentially cost beneficial.

F.6.6 SAMA 6: ENHANCE PLANT PROCEDURES TO EXPLICITLY CONFIRM ADEQUATE _SX007 THROTTLING

Due to variability in the temperature of the lake that serves as the water source for the Braidwood SX system, the _SX007 valve must be throttled to ensure the heat removal system is adequately balanced after RH initiation. Currently, the procedures do not explicitly require an independent check of the throttling action. Enhancing the procedures to explicitly direct such an independent check would improve the assessed reliability of the throttling action.

Assumptions:

It is assumed that inclusion of the explicit procedure step to independently check the valve throttle status will reduce the execution contribution to the point where it is a negligible contributor to the HEP. The total failure probability of the action is represented as the contribution from the cognitive component. Both the action to open the valve locally using the control switch (0SX007-ES13HMVOA) and the action to manually stroke the valve (0SX007-HW--HMVOA) has a cognitive component of 6.6E-04.

Unless the HEP is the lead action in a joint human error probability (JHEP), the value of the independent HEP has a small impact on the JHEP value. No changes are made to the JHEPs unless the chronologically first action is 0SX007-HW--HMVOA or 0SX007-ES13HMVOA.

PRA Model Changes to Model SAMA:

The database and recovery files were changed to use the updated HEPs reflecting the procedure modification.

Model Change(s):

The following modeling changes were made:

- 0SX007-HW--HMVOA: HEP changed to 6.6E-04.
- 0SX007-ES13HMVOA: HEP changed to 6.6E-04.
- 1RX-JHEP30-HOADA: Updated JHEP calc from 2.0E-04 to reflect modified independent HEP value: 6.6E-4 * ((1 + 19*1.0E-02) / 20) = 3.9E-05.

Results of SAMA Quantification:

Implementation of this SAMA yielded a moderate reduction in internal CDF and similar reductions in Dose-Risk and Offsite Economic Cost-Risk. The results are summarized in the following table:

	Internal CDF	Dose-Risk	OECR
Base Value	3.57E-05	113.76	$809,628
SAMA Value	3.04E-05	112.95	$805,981
Percent Change	14.8%	0.7%	0.5%

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

Release Category	$Freq._{BASE}$	$Freq._{SAMA}$	Dose-$Risk_{BASE}$	Dose-$Risk_{SAMA}$	$OECR_{BASE}$	$OECR_{SAMA}$
INTACT	1.34E-05	8.22E-06	3.32E-01	2.04E-01	$300	$184
SERF-TISGTR-HLF	8.12E-09	7.71E-09	3.01E-02	2.86E-02	$229	$217
SERF-SGTR-AFW-SC	1.48E-06	1.39E-06	5.70E+00	5.35E+00	$24,716	$23,213
LATE-BMMT-AFW	6.07E-07	3.52E-07	4.03E-02	2.34E-02	$31	$18
LATE-BMMT-NOAFW	9.95E-08	8.66E-08	1.90E-02	1.65E-02	$31	$27
LATE-CHR-AFW	1.37E-05	1.37E-05	2.14E+01	2.14E+01	$45,210	$45,210

Release Category	Freq.$_{BASE}$	Freq.$_{SAMA}$	Dose-Risk$_{BASE}$	Dose-Risk$_{SAMA}$	OECR$_{BASE}$	OECR$_{SAMA}$
LATE-CHR-NOAFW	7.51E-06	7.51E-06	6.59E+01	6.59E+01	$642,105	$642,105
LERF-ISLOCA	3.40E-07	3.40E-07	1.55E+01	1.55E+01	$54,400	$54,400
LERF-CI	3.63E-07	3.14E-07	1.18E+00	1.02E+00	$3,775	$3,266
LERF-CFE	3.14E-08	2.62E-08	2.92E-01	2.44E-01	$2,003	$1,672
LERF-SGTR-AFW	5.92E-08	5.55E-08	5.19E-01	4.86E-01	$4,422	$4,146
LERF-SGTR-NOAFW	9.64E-10	9.64E-10	2.98E-03	2.98E-03	$24	$24
LERF-ISGTR	2.57E-07	2.50E-07	2.80E+00	2.73E+00	$32,382	$31,500
Total	3.79E-05	3.23E-05	1.14E+02	1.13E+02	$809,628	$805,981

Applying the process described in Section F.4 yields an internal events cost-risk of $16,351,359. After accounting for “round up” of the base internal events cost-risk, this value is $16,351,616. The external events contributions are accounted for by multiplying this value by 2.8:

Total Cost-Risk$_{SAMA}$ = $16,351,616 * 2.8 = $45,784,525

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

SAMA 6 Averted Cost-Risk

Unit	Base Case Cost-Risk	Revised Cost-Risk	Averted Cost-Risk
Braidwood Unit 1	$46,412,800	$45,784,525	$628,275

Based on a $100,000 cost of implementation for Braidwood, the net value for this SAMA is $528,275 ($628,275 - $100,000), which indicates this SAMA is potentially cost beneficial.

F.6.7 SAMA 7: ESTABLISH FLOW TO THE RH HX ON RH PUMP START

To prevent overheating the RH pumps when they are operating on min-flow without CC cooling to the heat exchangers, procedure EP-0 (and potentially others) could be changed to direct the operators to align CC to the RH HX when the RH pumps start. This precludes the need for the operators to rely on a continuous action statement to protect the RH pumps if secondary side cooling is not established.

Assumptions:

It is assumed that the procedures can be modified in a way such that the flow to the HX is started when the corresponding RHR pump is confirmed to be running and that the step is written distinct manner (potentially with the caution that exists in the current FR-H.1 procedure related to the limitations on the RH pump run time without flow to the HX). It is assumed the impact of these changes can be approximated by crediting graphically distinct procedures and a “check” cue in the HRA methodology for the HFE 1RH-SP-X---HPMOA. The result is a reduction in the HEP from 7.3E-04 to 1.4E-04.

Unless the HEP is the lead action in a JHEP, the value of the independent HEP has a small impact on the JHEP value. No changes are made to the JHEPs unless the chronologically first action is 1RH-SP-X---HPMOA.

PRA Model Changes to Model SAMA:

The database and recovery files were changed to use the updated HEPs reflecting the procedure modification.

Model Change(s):

The following modeling changes were made:

- 1RH-SP-X---HPMOA: HEP changed from 7.3E-04 to 1.4E-04.
- 1RX-JHEP33-HOADA: Updated JHEP calc from 3.9E-05 to reflect modified independent HEP value: 1.4E-4 * ((1 + 19*2.7E-03) / 20) = 7.4E-06.
- 1RX-JHEP42-HOADA: Updated JHEP calc from 3.7E-05 to reflect modified independent HEP value: 1.4E-4 * ((1 + 19*9.6E-04) / 20) = 7.1E-06

Results of SAMA Quantification:

Implementation of this SAMA yielded a moderate reduction in internal CDF and similar reductions in Dose-Risk and Offsite Economic Cost-Risk. The results are summarized in the following table:

	Internal CDF	Dose-Risk	OECR
Base Value	3.57E-05	113.76	$809,628
SAMA Value	3.48E-05	113.61	$808,947
Percent Change	2.5%	0.1%	0.1%

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

Release Category	$Freq._{BASE}$	$Freq._{SAMA}$	Dose-$Risk_{BASE}$	Dose-$Risk_{SAMA}$	$OECR_{BASE}$	$OECR_{SAMA}$
INTACT	1.34E-05	1.26E-05	3.32E-01	3.12E-01	$300	$282
SERF-TISGTR-HLF	8.12E-09	8.12E-09	3.01E-02	3.01E-02	$229	$229
SERF-SGTR-AFW-SC	1.48E-06	1.46E-06	5.70E+00	5.62E+00	$24,716	$24,382
LATE-BMMT-AFW	6.07E-07	5.64E-07	4.03E-02	3.74E-02	$31	$29
LATE-BMMT-NOAFW	9.95E-08	9.81E-08	1.90E-02	1.87E-02	$31	$30
LATE-CHR-AFW	1.37E-05	1.37E-05	2.14E+01	2.14E+01	$45,210	$45,210
LATE-CHR-NOAFW	7.51E-06	7.51E-06	6.59E+01	6.59E+01	$642,105	$642,105
LERF-ISLOCA	3.40E-07	3.40E-07	1.55E+01	1.55E+01	$54,400	$54,400
LERF-CI	3.63E-07	3.55E-07	1.18E+00	1.15E+00	$3,775	$3,692
LERF-CFE	3.14E-08	3.05E-08	2.92E-01	2.84E-01	$2,003	$1,946
LERF-SGTR-AFW	5.92E-08	5.84E-08	5.19E-01	5.12E-01	$4,422	$4,362
LERF-SGTR-NOAFW	9.64E-10	9.64E-10	2.98E-03	2.98E-03	$24	$24
LERF-ISGTR	2.57E-07	2.56E-07	2.80E+00	2.79E+00	$32,382	$32,256
Total	3.79E-05	3.70E-05	1.14E+02	1.14E+02	$809,628	$808,947

Applying the process described in Section F.4 yields an internal events cost-risk of $16,536,283. After accounting for “round up” of the base internal events cost-risk, this value is $16,536,540. The external events contributions are accounted for by multiplying this value by 2.8:

$$\text{Total Cost-Risk}_{SAMA} = \$16,536,540 * 2.8 = \$46,302,312$$

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

SAMA 7 Averted Cost-Risk

Unit	Base Case Cost-Risk	Revised Cost-Risk	Averted Cost-Risk
Braidwood Unit 1	$46,412,800	$46,302,312	$110,488

Based on a $100,000 cost of implementation for Braidwood, the net value for this SAMA is $10,488 ($110,488 - $100,000), which indicates this SAMA is potentially cost beneficial.

F.6.8 SAMA 8: INSTALL KILL SWITCHES FOR THE FIRE PROTECTION PUMPS IN THE MCR

Currently, it is not possible to terminate all flow from the fire protection system in the main control room (MCR). In the event of a flood caused by a fire protection system break, the availability of controls in the MCR that would allow the operators to shut down the fire protection pumps would increase the likelihood that the flood could be terminated before critical equipment is damaged.

Assumptions:

Installation of kill switches in the MCR will reduce the time required to perform the action to terminate the flood and potentially in a simplification of the control scheme. Each pump is assumed to have a dedicated, two position control switch that is distinct from the other controls on the main control room fire protection control panel.

With the revised controls proposed for this SAMA, the manipulation time for this action is assumed to be 3 minutes (1 minute for each pump).

The flood mitigation factors include multiple actions, including the initial flood termination action, but are not wholly determined by the flood termination action HEP. The flood mitigation factors were recalculated using the above assumptions.

PRA Model Changes to Model SAMA:

A recovery file was developed to modify the cutsets to use the updated Fire Protection flood mitigation factors the Auxiliary Building Fire Protection floods.

Model Change(s):

The following changes were made to the cutsets:

- FLMITIG--G-T1-FP: Probability changed from 2.23E-04 to 1.10E-04.
- FLMITIG-M1-T1-FP: Probability changed from 3.33E-04 to 1.66E-04.
- FLMITIG-M2-T1-FP: Probability changed from 2.19E-03 to 1.89E-03.
- FLMITIG-M3-T1-FP: Probability changed from 6.94E-03 to 3.88E-03

Results of SAMA Quantification:

Implementation of this SAMA yielded a moderate reduction in internal CDF and similar reductions in Dose-Risk and Offsite Economic Cost-Risk. The results are summarized in the following table:

	Internal CDF	Dose-Risk	OECR
Base Value	3.57E-05	113.76	$809,628
SAMA Value	3.42E-05	111.07	$800,366
Percent Change	4.2%	2.4%	1.1%

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

Release Category	$Freq._{BASE}$	$Freq._{SAMA}$	$Dose\text{-}Risk_{BASE}$	$Dose\text{-}Risk_{SAMA}$	$OECR_{BASE}$	$OECR_{SAMA}$
INTACT	1.34E-05	1.34E-05	3.32E-01	3.32E-01	$300	$300
SERF-TISGTR-HLF	8.12E-09	8.12E-09	3.01E-02	3.01E-02	$229	$229
SERF-SGTR-AFW-SC	1.48E-06	1.48E-06	5.70E+00	5.70E+00	$24,716	$24,716
LATE-BMMT-AFW	6.07E-07	6.07E-07	4.03E-02	4.03E-02	$31	$31
LATE-BMMT-NOAFW	9.95E-08	9.95E-08	1.90E-02	1.90E-02	$31	$31
LATE-CHR-AFW	1.37E-05	1.23E-05	2.14E+01	1.92E+01	$45,210	$40,590
LATE-CHR-NOAFW	7.51E-06	7.46E-06	6.59E+01	6.55E+01	$642,105	$637,830
LERF-ISLOCA	3.40E-07	3.40E-07	1.55E+01	1.55E+01	$54,400	$54,400
LERF-CI	3.63E-07	3.49E-07	1.18E+00	1.13E+00	$3,775	$3,630
LERF-CFE	3.14E-08	2.99E-08	2.92E-01	2.78E-01	$2,003	$1,908

Release Category	Freq.$_{BASE}$	Freq.$_{SAMA}$	Dose-Risk$_{BASE}$	Dose-Risk$_{SAMA}$	OECR$_{BASE}$	OECR$_{SAMA}$
LERF-SGTR-AFW	5.92E-08	5.92E-08	5.19E-01	5.19E-01	$4,422	$4,422
LERF-SGTR-NOAFW	9.64E-10	9.64E-10	2.98E-03	2.98E-03	$24	$24
LERF-ISGTR	2.57E-07	2.56E-07	2.80E+00	2.79E+00	$32,382	$32,256
Total	3.79E-05	3.64E-05	1.14E+02	1.11E+02	$809,628	$800,366

Applying the process described in Section F.4 yields an internal events cost-risk of $16,314,362. After accounting for "round up" of the base internal events cost-risk, this value is $16,314,619. The external events contributions are accounted for by multiplying this value by 2.8:

$$\text{Total Cost-Risk}_{SAMA} = \$16,314,619 * 2.8 = \$45,680,933$$

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

SAMA 8 Averted Cost-Risk

Unit	Base Case Cost-Risk	Revised Cost-Risk	Averted Cost-Risk
Braidwood Unit 1	$46,412,800	$45,680,933	$731,867

Based on a $338,830 cost of implementation for Braidwood, the net value for this SAMA is $393,037 ($731,867 - $338,830), which indicates this SAMA is potentially cost beneficial.

F.6.9 SAMA 9: INSTALL FLOW RESTRICTORS IN FIRE PROTECTION PIPES

Large breaks in the fire protection systems are significant contributors to plant risk. Installing flow restrictors in the auxiliary building piping would increase the time available to respond to these flooding events. Locating flow restrictors outside the auxiliary building upstream of valves 0FP209A, 0FP209B, and FP033 would provide adequate protection for auxiliary building floods.

Assumptions:

It is assumed that fire protection code will allow the installation of flow restrictors in the fire protection system lines. If this is not possible, it is assumed that a flow analysis can be performed that will allow the throttling of the 0FP209A, 0FP209B, and 0FP033 valves (which may need to be replaced by valves of a different type) to achieve similar results.

It is assumed that the flow restrictions will limit flow of Fire Protection breaks in the Auxiliary building to 1000 gpm and that 1000 gpm is adequate to meet fire suppression requirements.

The increase in the time available to terminate the fire protection flood reduces the flood mitigation factor to 1.2E-4. Because the flow restrictors would limit flow to 1000 gpm for all Auxiliary Building Fire Protection breaks, this flood mitigation factor is assumed to be applicable to all Auxiliary Building Fire Protection flooding scenarios.

PRA Model Changes to Model SAMA:

A recovery file was developed to modify the cutsets to use the updated Fire Protection flood mitigation factor for all Auxiliary Building Fire Protection floods.

Model Change(s):

The following changes were made to the cutsets:

- FLMITIG--G-T1-FP: Probability changed from 2.23E-04 to 1.2E-04.
- FLMITIG-M1-T1-FP: Probability changed from 3.33E-04 to 1.2E-04.
- FLMITIG-M2-T1-FP: Probability changed from 2.19E-03 to 1.2E-04.
- FLMITIG-M3-T1-FP: Probability changed from 6.94E-03 to 1.2E-04

Results of SAMA Quantification:

Implementation of this SAMA yielded a moderate reduction in internal CDF and similar reductions in Dose-Risk and Offsite Economic Cost-Risk. The results are summarized in the following table:

	Internal CDF	**Dose-Risk**	**OECR**
Base Value	3.57E-05	113.76	$809,628
SAMA Value	3.26E-05	107.89	$789,960
Percent Change	8.7%	5.2%	2.4%

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

Release Category	Freq.BASE	Freq.SAMA	Dose-RiskBASE	Dose-RiskSAMA	OECRBASE	OECRSAMA
INTACT	1.34E-05	1.34E-05	3.32E-01	3.32E-01	$300	$300
SERF-TISGTR-HLF	8.12E-09	8.12E-09	3.01E-02	3.01E-02	$229	$229
SERF-SGTR-AFW-SC	1.48E-06	1.48E-06	5.70E+00	5.70E+00	$24,716	$24,716
LATE-BMMT-AFW	6.07E-07	6.07E-07	4.03E-02	4.03E-02	$31	$31
LATE-BMMT-NOAFW	9.95E-08	9.95E-08	1.90E-02	1.90E-02	$31	$31
LATE-CHR-AFW	1.37E-05	1.06E-05	2.14E+01	1.65E+01	$45,210	$34,980
LATE-CHR-NOAFW	7.51E-06	7.41E-06	6.59E+01	6.51E+01	$642,105	$633,555
LERF-ISLOCA	3.40E-07	3.40E-07	1.55E+01	1.55E+01	$54,400	$54,400
LERF-CI	3.63E-07	3.33E-07	1.18E+00	1.08E+00	$3,775	$3,463
LERF-CFE	3.14E-08	2.83E-08	2.92E-01	2.63E-01	$2,003	$1,806
LERF-SGTR-AFW	5.92E-08	5.92E-08	5.19E-01	5.19E-01	$4,422	$4,422
LERF-SGTR-NOAFW	9.64E-10	9.64E-10	2.98E-03	2.98E-03	$24	$24
LERF-ISGTR	2.57E-07	2.54E-07	2.80E+00	2.77E+00	$32,382	$32,004
Total	3.79E-05	3.46E-05	1.14E+02	1.08E+02	$809,628	$789,960

Applying the process described in Section F.4 yields an internal events cost-risk of $16,018,421. After accounting for "round up" of the base internal events cost-risk, this value is $16,018,678. The external events contributions are accounted for by multiplying this value by 2.8:

$$\text{Total Cost-Risk}_{SAMA} = \$16,018,678 * 2.8 = \$44,852,298$$

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

SAMA 9 Averted Cost-Risk

Unit	Base Case Cost-Risk	Revised Cost-Risk	Averted Cost-Risk
Braidwood Unit 1	$46,412,800	$44,852,298	$1,560,502

Based on a $349,300 cost of implementation for Braidwood, the net value for this SAMA is $1,211,202 ($1,560,502 - $349,300), which indicates this SAMA is potentially cost beneficial.

F.6.10 SAMA 10: ALTER DUCTWORK BETWEEN THE AUX BLDG SUMP DRAIN ROOM AND THE SX PUMP ROOM

Currently, the ductwork between the Auxiliary Building Sump Drain Room and the SX Pump Rooms provides a flowpath for flood water when the Auxiliary Building Sump Drain Room fills with water (at a depth of about 12 feet). Water then flows through the ductwork to the SX pump room and damages the SX pumps. Eliminating this pathway will increase the time available to mitigate the flooding event by precluding SX pump damage from the flooding event.

Assumptions:

The ductwork modification prevents water intrusion into the SX pump room duct until water level reaches the 364' elevation. It is assumed that the actual failure level is the same as that for the other critical equipment located on that level such that the time available for flood termination is the same as what is currently used for the internal flooding assessment.

This SAMA eliminates the "T1" flooding scenarios that are related to failing SX due to the existing duct connections between the SX pumps rooms and the Auxiliary Building Sump Drain Room.

The flood mitigation factors for the WS and SX floods are simplified to the HEPs for termination of the flood before the level reaches elevation 364'.

PRA Model Changes to Model SAMA:

A recovery file was developed to modify the cutsets to use the updated Fire Protection flood mitigation factor for all Auxiliary Building floods.

Model Change(s):

The following changes were made to the cutsets:

- Set probability of the following "T1" flood events to 0.0: FLMITIG-FPCVCOOL, FLMITIG--G-T1-FP, FLMITIG--G-T1-SX, FLMITIG--G-T1-WS, FLMITIG-M1-T1-FP, FLMITIG-M1-T1-WS, FLMITIG-M2-T1-FP, FLMITIG-M3-T1-FP, FLMITIG-M3-T1-WS, FLMITIG--M-T1-SX.
- FLMITIG-M3-T2-WS: Probability changed from 2.14E-04 to 1.8E-04.
- FLMITIG--M-T2-SX: Probability changed from 2.09E-03 to 1.4E-04

Results of SAMA Quantification:

Implementation of this SAMA yielded a moderate reduction in internal CDF and similar reductions in Dose-Risk and Offsite Economic Cost-Risk. The results are summarized in the following table:

	Internal CDF	Dose-Risk	OECR
Base Value	3.57E-05	113.76	$809,628
SAMA Value	3.10E-05	100.03	$723,479
Percent Change	13.2%	12.1%	10.6%

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

Release Category	$Freq._{BASE}$	$Freq._{SAMA}$	Dose-$Risk_{BASE}$	Dose-$Risk_{SAMA}$	$OECR_{BASE}$	$OECR_{SAMA}$
INTACT	1.34E-05	1.34E-05	3.32E-01	3.32E-01	$300	$300
SERF-TISGTR-HLF	8.12E-09	8.12E-09	3.01E-02	3.01E-02	$229	$229
SERF-SGTR-AFW-SC	1.48E-06	1.48E-06	5.70E+00	5.70E+00	$24,716	$24,716
LATE-BMMT-AFW	6.07E-07	6.07E-07	4.03E-02	4.03E-02	$31	$31
LATE-BMMT-NOAFW	9.95E-08	9.95E-08	1.90E-02	1.90E-02	$31	$31
LATE-CHR-AFW	1.37E-05	9.84E-06	2.14E+01	1.54E+01	$45,210	$32,472
LATE-CHR-NOAFW	7.51E-06	6.70E-06	6.59E+01	5.88E+01	$642,105	$572,850
LERF-ISLOCA	3.40E-07	3.40E-07	1.55E+01	1.55E+01	$54,400	$54,400
LERF-CI	3.63E-07	2.69E-07	1.18E+00	8.74E-01	$3,775	$2,798
LERF-CFE	3.14E-08	2.70E-08	2.92E-01	2.51E-01	$2,003	$1,723
LERF-SGTR-AFW	5.92E-08	5.92E-08	5.19E-01	5.19E-01	$4,422	$4,422
LERF-SGTR-NOAFW	9.64E-10	9.64E-10	2.98E-03	2.98E-03	$24	$24
LERF-ISGTR	2.57E-07	2.34E-07	2.80E+00	2.55E+00	$32,382	$29,484
Total	3.79E-05	3.31E-05	1.14E+02	1.00E+02	$809,628	$723,479

Applying the process described in Section F.4 yields an internal events cost-risk of $14,738,413. After accounting for “round up” of the base internal events cost-risk, this value is $14,738,670. The external events contributions are accounted for by multiplying this value by 2.8:

$$\text{Total Cost-Risk}_{SAMA} = \$14,738,670 * 2.8 = \$41,268,276$$

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

SAMA 10 Averted Cost-Risk

Unit	Base Case Cost-Risk	Revised Cost-Risk	Averted Cost-Risk
Braidwood Unit 1	$46,412,800	$41,268,276	$5,144,524

Based on a $1,320,300 cost of implementation for Braidwood, the net value for this SAMA is $3,824,224 ($5,144,524 - $1,320,300), which indicates this SAMA is potentially cost beneficial.

F.6.11 SAMA 11: IMPLEMENT DMS

The diverse and flexible coping strategies (FLEX) guide identifies different means of addressing required plant functions in extreme accident conditions, but for the SAMA analysis a specific approach, called the Diverse Mitigation System (DMS), is proposed. A portable 480V AC generator is proposed as a means of supporting long term diesel driven AFW operation by means of maintaining instrumentation and control power for the system by energizing the buses used for the battery chargers. A portable, engine driven SG makeup pump would provide an alternate means of SG makeup, with injection connections available on different divisions. Fire protection should provide both condensate storage tank (CST) makeup and a suction source connection for the portable SG makeup pump. Use of high temperature RCP seals would limit primary system leakage and the positive displacement pump could be replaced by one that could be powered by the portable generator for long term RCS makeup. A means of providing borated makeup to the RWST is also required, which could potentially be performed using the fire protection system and an eductor. Finally, a connection point to an outside source would have to be provided for the containment spray system for long term spray capability in an SBO.

Assumptions:

SAMA 11 was generally identified as a means of mitigating scenarios in which loss of SG makeup is a slowly developing evolution, such as in SBO events where battery depletion eventually fails diesel driven AFW or in loss of SX cases in which the AFW pumps (motor or diesel driven) may be able to run for some time before failure. No credit is taken for the DMS in LOCA or ATWS scenarios. The DMS is credited in SGTR cases as most cases include success of injection where time would be available to recover steam generator makeup. Prior to core damage, activity levels are expected to be low enough to perform any alignment required.

The DMS capabilities are assumed to be represented by a lower RCP seal LOCA probability and indefinite steam generator makeup capability. The “no leak” seals are assumed to reduce the seal LOCA probability by a factor of 1000. The steam generator makeup capability includes alignment and control of a portable 480V generator to support diesel driven AFW makeup or alignment and control of a portable SG makeup pump. A new event with a failure probability of 1E-2 is used for this function.

It is assumed that the cognitive failure to diagnose the need for secondary cooling (1FW-FRH1---HSGOA), which is related to the AFW X-tie, FW restoration, and bleed and feed, will also fail DMS. In addition, any dependent combinations are also assumed to fail DMS.

PRA Model Changes to Model SAMA:

The fault tree was updated to incorporate the DMS event and cognitive failure logic. After quantification, the deleted flag “FLAG-SEAL-LOCA” is restored to the cutsets in the cutset editor and assigned a value of 1E-3. Because the cutsets already include events that represent seal LOCA probabilities that are less than 1.0, this process ultimately reduces the probability that a seal LOCA occurs to less than the assumed value of 1E-3, but it conservatively shows an increased averted cost-risk for the SAMA.

Model Change(s):

The following modeling changes were made:

- New event 1DMS: DMS - OPS FAIL TO ALIGN/USE 480V CHARGER OR PORTABLE SG MAKEUP PUMP, 1.0E-02
- New OR gate 1DMS-FAILS: Include new event 1DMS, 1FW-FRH1---HSGOA, 1RX-JHEP03-HOADA and similar events for the following JHEP combinations: 07, 09, 11, 12, 14, 17, 21, 24, 25, 27, 39, 49, 50, 54, 58, 64, 74, and 80.
- Under gate 1AFW: Added NEW gate 1DMS-FAILS.
- Under gate 1AFW-LOOP-3SG: Added NEW gate 1DMS-FAILS.
- Under gate 1AFW-LOOP-2SG: Added NEW gate 1DMS-FAILS.
- Under gate 1AFW-SBO-3SG: Added NEW gate 1DMS-FAILS.
- Under gate 1AFW-SBO-2SG: Added NEW gate 1DMS-FAILS.
- Under gate 1AFW-LOB-MDP-3SG: Added NEW gate 1DMS-FAILS.

- Under gate 1AFW-LOB-MDP-2SG: Added NEW gate 1DMS-FAILS.
- Under gate 1AFW-LOB-DDP-3SG: Added NEW gate 1DMS-FAILS.
- Under gate 1AFW-LOB-DDP-2SG: Added NEW gate 1DMS-FAILS.
- Under gate 1AF-UBR-LATE: Added NEW gate 1DMS-FAILS.
- Under gate 1AF-UBR-LATE: Added NEW gate 1DMS-FAILS.
- Under gate 1AF-DP-LATE: Added NEW gate 1DMS-FAILS.

Post quantification, set flag FLAG-SEAL-LOCA to a probability of 1E-3.

Results of SAMA Quantification:

Implementation of this SAMA yielded a moderate reduction in internal CDF and similar reductions in Dose-Risk and Offsite Economic Cost-Risk. The results are summarized in the following table:

	Internal CDF	Dose-Risk	OECR
Base Value	3.57E-05	113.76	$809,628
SAMA Value	1.09E-05	26.57	$126,487
Percent Change	69.5%	76.6%	84.4%

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

Release Category	$Freq._{BASE}$	$Freq._{SAMA}$	$Dose\text{-}Risk_{BASE}$	$Dose\text{-}Risk_{SAMA}$	$OECR_{BASE}$	$OECR_{SAMA}$
INTACT	1.34E-05	8.74E-06	3.32E-01	2.17E-01	$300	$196
SERF-TISGTR-HLF	8.12E-09	1.95E-09	3.01E-02	7.23E-03	$229	$55
SERF-SGTR-AFW-SC	1.48E-06	1.48E-06	5.70E+00	5.70E+00	$24,716	$24,716
LATE-BMMT-AFW	6.07E-07	4.04E-07	4.03E-02	2.68E-02	$31	$21
LATE-BMMT-NOAFW	9.95E-08	4.45E-08	1.90E-02	8.50E-03	$31	$14
LATE-CHR-AFW	1.37E-05	2.42E-08	2.14E+01	3.78E-02	$45,210	$80
LATE-CHR-NOAFW	7.51E-06	4.28E-07	6.59E+01	3.76E+00	$642,105	$36,594
LERF-ISLOCA	3.40E-07	3.40E-07	1.55E+01	1.55E+01	$54,400	$54,400
LERF-CI	3.63E-07	8.70E-08	1.18E+00	2.83E-01	$3,775	$905
LERF-CFE	3.14E-08	9.14E-09	2.92E-01	8.51E-02	$2,003	$583

Release Category	$Freq._{BASE}$	$Freq._{SAMA}$	$Dose\text{-}Risk_{BASE}$	$Dose\text{-}Risk_{SAMA}$	$OECR_{BASE}$	$OECR_{SAMA}$
LERF-SGTR-AFW	5.92E-08	5.91E-08	5.19E-01	5.18E-01	$4,422	$4,415
LERF-SGTR-NOAFW	9.64E-10	9.64E-10	2.98E-03	2.98E-03	$24	$24
LERF-ISGTR	2.57E-07	3.56E-08	2.80E+00	3.88E-01	$32,382	$4,486
Total	3.79E-05	1.17E-05	1.14E+02	2.66E+01	$809,628	$126,487

Applying the process described in Section F.4 yields an internal events cost-risk of $2,999,852. After accounting for "round up" of the base internal events cost-risk, this value is $3,000,109. The external events contributions are accounted for by multiplying this value by 2.8:

$$\text{Total Cost-Risk}_{SAMA} = \$3{,}000{,}109 * 2.8 = \$8{,}400{,}305$$

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

SAMA 11 Averted Cost-Risk

Unit	Base Case Cost-Risk	Revised Cost-Risk	Averted Cost-Risk
Braidwood Unit 1	$46,412,800	$8,400,305	$38,012,495

Based on a $13,030,000 cost of implementation for Braidwood, the net value for this SAMA is $24,982,495 ($38,012,495 - $13,030,000), which indicates this SAMA is potentially cost beneficial.

F.6.12 SAMA 13: ALTERNATE AFW COOLING WITH SEAL PROTECTION

For loss of SX events with consequential LOOP, the AFW lube oil coolers are unavailable and the AFW pumps are assumed to fail. The motor driven AFW pump discharge flow could be routed back to the lube oil coolers to provide a self-cooling mechanism that would eliminate the SX dependence. The cooling water return flow could potentially be returned to the AFW pump discharge path. For RCP seal protection, replacing the positive displacement pump (PDP) with a self-cooled pump with the capability to auto start on loss of charging flow/and or high seal injection water temp would provide a success path.

Assumptions:

This SAMA is assumed to eliminate the SX dependence for motor driven AFW pump operation. The diesel driven AFW pumps is not modified for this SAMA given that an additional change would be required to provide flow to the cubicle coolers and because power is available to the motor driven AFW pump for most of the scenarios this SAMA is intended to address.

The seal injection pump is assumed to have a failure probability of 1E-3. Division 1 and division 2 emergency 480V AC power are assumed to be available to the new seal injection pump with an automatic transfer switch that is 100% reliable.

The AFW cross-tie is assumed to be unavailable for dual unit LOSX events (even after implementation) because the "A" pump would be needed on the opposite unit.

PRA Model Changes to Model SAMA:

The fault tree was updated to incorporate the self-cooled pump and power supplies under the existing seal injection logic. In addition, the SX dependencies were removed for the motor driven AFW pump.

Model Change(s):

The following modeling changes were made:

- New OR gate 1SAMA13-SEAL-INJ: Include new event 1SAMA13 and new gate 1SAMA13-POWER.
- New AND gate 1SAMA13-POWER: Include existing gates 1AP-BUS131X4 and 1AP-BUS132X4.
- New event 1SAMA13: SAMA 13 SEAL INJECTION PUMP FAILS; 1.00E-03.
- Under existing gate 1CSLOCA: Added NEW gate 1SAMA13-SEAL-INJ.
- Under existing gate 1CSLOCA-IE: Added NEW gate 1SAMA13-SEAL-INJ.
- Under existing gate 1LOSC-141: Added NEW gate 1SAMA13-SEAL-INJ.
- Under existing gate 1LOSC-142: Added NEW gate 1SAMA13-SEAL-INJ.
- Under existing gate 1LOSC-LOOP: Added NEW gate 1SAMA13-SEAL-INJ.
- Under existing gate 1RCP-SEALLOCA-SLB: Added NEW gate 1SAMA13-SEAL-INJ.
- Under existing gates 1AF-PUMP1A-FR-HW-X, 1AF-PUMP1A-FR-HW, and Removed gate 0SX-ALL----CSRPG-FT.
- Under existing gates 1AF-PUMP-1A-FTR-SUPPORT and 1AF-TRAIN-1A-X-ND: Removed gate 1AF-PUMP1A-OIL.
- Under existing gate 2AF-XTIE-AF1A-FTR: Removed gate 1AF-PUMP1A-OIL-XTIE.
- Under existing gate 1AFW-SBO-MDP: Removed gate 1AFW-MDP-ND-SX.

Results of SAMA Quantification:

Implementation of this SAMA yielded a moderate reduction in internal CDF and similar reductions in Dose-Risk and Offsite Economic Cost-Risk. The results are summarized in the following table:

	Internal CDF	Dose-Risk	OECR
Base Value	3.57E-05	113.76	$809,628
SAMA Value	1.21E-05	26.47	$120,691
Percent Change	66.1%	76.7%	85.1%

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

Release Category	Freq.$_{BASE}$	Freq.$_{SAMA}$	Dose-Risk$_{BASE}$	Dose-Risk$_{SAMA}$	OECR$_{BASE}$	OECR$_{SAMA}$
INTACT	1.34E-05	1.00E-05	3.32E-01	2.48E-01	$300	$224
SERF-TISGTR-HLF	8.12E-09	8.12E-09	3.01E-02	3.01E-02	$229	$229
SERF-SGTR-AFW-SC	1.48E-06	1.48E-06	5.70E+00	5.70E+00	$24,716	$24,716
LATE-BMMT-AFW	6.07E-07	4.09E-07	4.03E-02	2.72E-02	$31	$21
LATE-BMMT-NOAFW	9.95E-08	9.95E-08	1.90E-02	1.90E-02	$31	$31
LATE-CHR-AFW	1.37E-05	3.32E-07	2.14E+01	5.18E-01	$45,210	$1,096
LATE-CHR-NOAFW	7.51E-06	3.08E-07	6.59E+01	2.70E+00	$642,105	$26,334
LERF-ISLOCA	3.40E-07	3.40E-07	1.55E+01	1.55E+01	$54,400	$54,400
LERF-CI	3.63E-07	1.43E-07	1.18E+00	4.65E-01	$3,775	$1,487
LERF-CFE	3.14E-08	9.31E-09	2.92E-01	8.67E-02	$2,003	$594
LERF-SGTR-AFW	5.92E-08	5.92E-08	5.19E-01	5.19E-01	$4,422	$4,422
LERF-SGTR-NOAFW	9.64E-10	7.65E-10	2.98E-03	2.36E-03	$24	$19
LERF-ISGTR	2.57E-07	5.65E-08	2.80E+00	6.16E-01	$32,382	$7,119
Total	3.79E-05	1.32E-05	1.14E+02	2.65E+01	$809,628	$120,691

Applying the process described in Section F.4 yields an internal events cost-risk of $2,942,630. After accounting for "round up" of the base internal events cost-risk, this value is $2,942,887. The external events contributions are accounted for by multiplying this value by 2.8:

$$\text{Total Cost-Risk}_{SAMA} = \$2,942,887 * 2.8 = \$8,240,084$$

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

SAMA 13 Averted Cost-Risk

Unit	Base Case Cost-Risk	Revised Cost-Risk	Averted Cost-Risk
Braidwood Unit 1	$46,412,800	$8,240,084	$38,172,716

Based on a $5,951,110 cost of implementation for Braidwood, the net value for this SAMA is $32,221,606 ($38,172,716 - $5,951,110), which indicates this SAMA is potentially cost beneficial.

F.6.13 SAMA 14 AUTOMATED RWST MAKEUP

For SGTR scenarios in which cooldown has failed, installing an automated RWST makeup system could provide a means of maintaining injection indefinitely. The makeup pump should be powered from a diesel backed bus. A boron source is required to ensure criticality does not occur. Including an alarm that identifies system actuation would provide an additional cue to address plant issues that have led to RWST depletion.

For non-SGTR scenarios, the availability of automated RWST makeup would extend the time available to transition to recirculation mode.

Assumptions:

The RWST makeup capability will extend the time available to perform required actions in SGTR scenarios and scenarios requiring transition to recirculation mode, but it is assumed that the actions to control injection and perform a cooldown will eventually have to be taken to reach a successful endstate (i.e., injection with RWST makeup alone is not a success state). For this evaluation, it is assumed that the HEPs for the following operator actions are reduced by a factor of 10:

- 1SI-HPR----HSYOA: OPERATORS FAIL TO ESTABLISH HIGH PRESSURE RECIRC (SLOW EVENT)

- 1RC-LCD----HSYOA: OPERATORS FAIL TO TERMINATE BREAK FLOW ON SGTR

In addition, the JHEPs including those actions were reviewed to determine which of the dependent actions would be impacted by this SAMA. Most of the JHEPs were already set to the floor value of 1.0E-06, but 1RX-JHEP28-HOADA, 1RX-JHEP51-HOADA and 1RX-JHEP71-HOADA would be impacted. 1RX-JHEP51-HOADA and 1RX-JHEP71-HOADA, which are related to establishing recirculation, were set to 0.0 for simplicity. 1RX-JHEP28-HOADA, which is the dependent combination of 1RC-DS-SGTRHDVOA and 1RC-LCD----HSYOA, is impacted, but the impact is on the chronologically second, or dependent, action of the pair. The impact is limited in these cases, but the JHEP was revised to reflect a factor of 10 reduction in 1RC-LCD----HSYOA and a change in the assessed dependence level from MODERATE to LOW.

PRA Model Changes to Model SAMA:

The cutsets were updated to account for the changes to the HEPs and JHEPs due to the increased time available for action.

Model Change(s):

The following modeling changes were made to the results cutsets:

- Event 1SI-HPR----HSYOA: HEP changed from 6.8E-03 to 6.8E-04.
- Event 1RC-LCD----HSYOA: HEP changed from 3.2E-03 to 3.2E-04.
- Event 1RX-JHEP51-HOADA: Set to 0.0.
- Event 1RX-JHEP71-HOADA: Set to 0.0.
- 1RX-JHEP28-HOADA: Updated JHEP calc from 3.3E-04 to reflect modified independent HEP value: 6.3E-3 * ((1 + 19*3.2E-04) / 20) = 3.2E-04

Results of SAMA Quantification:

Implementation of this SAMA yielded a moderate reduction in internal CDF and similar reductions in Dose-Risk and Offsite Economic Cost-Risk. The results are summarized in the following table:

	Internal CDF	Dose-Risk	OECR
Base Value	3.57E-05	113.76	$809,628
SAMA Value	3.53E-05	113.41	$807,481
Percent Change	1.1%	0.3%	0.3%

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

Release Category	$Freq._{BASE}$	$Freq._{SAMA}$	Dose-$Risk_{BASE}$	Dose-$Risk_{SAMA}$	$OECR_{BASE}$	$OECR_{SAMA}$
INTACT	1.34E-05	1.31E-05	3.32E-01	3.25E-01	$300	$293
SERF-TISGTR-HLF	8.12E-09	7.80E-09	3.01E-02	2.89E-02	$229	$220
SERF-SGTR-AFW-SC	1.48E-06	1.42E-06	5.70E+00	5.47E+00	$24,716	$23,714
LATE-BMMT-AFW	6.07E-07	6.05E-07	4.03E-02	4.02E-02	$31	$31
LATE-BMMT-NOAFW	9.95E-08	8.46E-08	1.90E-02	1.62E-02	$31	$26
LATE-CHR-AFW	1.37E-05	1.37E-05	2.14E+01	2.14E+01	$45,210	$45,210
LATE-CHR-NOAFW	7.51E-06	7.51E-06	6.59E+01	6.59E+01	$642,105	$642,105
LERF-ISLOCA	3.40E-07	3.40E-07	1.55E+01	1.55E+01	$54,400	$54,400
LERF-CI	3.63E-07	3.61E-07	1.18E+00	1.17E+00	$3,775	$3,754
LERF-CFE	3.14E-08	3.12E-08	2.92E-01	2.90E-01	$2,003	$1,991
LERF-SGTR-AFW	5.92E-08	5.64E-08	5.19E-01	4.94E-01	$4,422	$4,213
LERF-SGTR-NOAFW	9.64E-10	9.64E-10	2.98E-03	2.98E-03	$24	$24
LERF-ISGTR	2.57E-07	2.50E-07	2.80E+00	2.73E+00	$32,382	$31,500
Total	3.79E-05	3.75E-05	1.14E+02	1.13E+02	$809,628	$807,481

Applying the process described in Section F.4 yields an internal events cost-risk of $16,521,918. After accounting for “round up” of the base internal events cost-risk, this value is $16,522,175. The external events contributions are accounted for by multiplying this value by 2.8:

$$\text{Total Cost-Risk}_{SAMA} = \$16,522,175 * 2.8 = \$46,262,090$$

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

SAMA 14 Averted Cost-Risk

Unit	Base Case Cost-Risk	Revised Cost-Risk	Averted Cost-Risk
Braidwood Unit 1	$46,412,800	$46,262,090	$150,710

Based on a $3,800,000 cost of implementation for Braidwood, the net value for this SAMA is -$3,649,290 ($150,710 - $3,800,000), which indicates this SAMA is not cost beneficial.

F.6.14 SAMA 15 RESOLVE REGULATORY ISSUES AND COMPLETE IMPLEMENTATION OF THE INTER UNIT AFW CROSS-TIE

The inter unit AFW cross-tie is in place at the site, but regulatory issues must be resolved before it can be considered "implemented". Once the process is complete, it will allow one unit to use the other unit's AFW system to provide SG makeup. The cross-tie valve requires local, manual action for operation.

Due to the timing of the submittal of the license renewal application, the official PRA model does not credit the AFW cross-tie action, but this SAMA documents the estimated impact of implementing the cross-tie in the existing model.

Section F.7.4 includes a sensitivity analysis that assesses the impact of implementing the AFW cross-tie on the cost benefit results of the remaining SAMAs.

Assumptions:

The AFW cross-tie action is currently included in the PRA model (1AF-XTIE—EHXVOA) with the action’s execution failure probability set to 1.0. The failure to diagnose the need to initiate the AFW cross-tie alignment is already included in the model with a non 1.0 probability. The diagnosis component of the action is represented by a common cognitive term that addresses the set of potential actions that are performed in response to loss of secondary side heat removal (for example, alignment of the startup FW pump for SG makeup). Because this event is already incorporated into the analysis in a way that includes use of the cross-tie, no changes are required to the cognitive term or the associated joint HEPs.

The execution failure probability was previously estimated to be 2.4E-2 and that estimate is used to represent the cross-tie alignment failure probability in this analysis.

PRA Model Changes to Model SAMA:

The cutsets were updated to account for the completion of the AFW cross-tie modification.

Model Change(s):

The following modeling changes were made to the results cutsets:

- Event 1AF-XTIE--EHXVOA: HEP changed from 1.0 to 2.4E-02.

Results of SAMA Quantification:

Implementation of this SAMA yielded a moderate reduction in internal CDF and similar reductions in Dose-Risk and Offsite Economic Cost-Risk. The results are summarized in the following table:

	Internal CDF	Dose-Risk	OECR
Base Value	3.57E-05	113.76	$809,628
SAMA Value	3.48E-05	111.44	$786,928
Percent Change	2.5%	2.0%	2.8%

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

Release Category	$Freq._{BASE}$	$Freq._{SAMA}$	Dose-$Risk_{BASE}$	Dose-$Risk_{SAMA}$	$OECR_{BASE}$	$OECR_{SAMA}$
INTACT	1.34E-05	1.28E-05	3.32E-01	3.17E-01	$300	$287
SERF-TISGTR-HLF	8.12E-09	2.79E-09	3.01E-02	1.04E-02	$229	$79
SERF-SGTR-AFW-SC	1.48E-06	1.48E-06	5.70E+00	5.70E+00	$24,716	$24,716
LATE-BMMT-AFW	6.07E-07	6.07E-07	4.03E-02	4.03E-02	$31	$31
LATE-BMMT-NOAFW	9.95E-08	6.16E-08	1.90E-02	1.18E-02	$31	$19
LATE-CHR-AFW	1.37E-05	1.37E-05	2.14E+01	2.14E+01	$45,210	$45,210
LATE-CHR-NOAFW	7.51E-06	7.28E-06	6.59E+01	6.39E+01	$642,105	$622,440
LERF-ISLOCA	3.40E-07	3.40E-07	1.55E+01	1.55E+01	$54,400	$54,400
LERF-CI	3.63E-07	3.57E-07	1.18E+00	1.16E+00	$3,775	$3,713
LERF-CFE	3.14E-08	3.10E-08	2.92E-01	2.89E-01	$2,003	$1,978
LERF-SGTR-AFW	5.92E-08	5.92E-08	5.19E-01	5.19E-01	$4,422	$4,422
LERF-SGTR-NOAFW	9.64E-10	9.64E-10	2.98E-03	2.98E-03	$24	$24

Release Category	$Freq._{BASE}$	$Freq._{SAMA}$	$Dose\text{-}Risk_{BASE}$	$Dose\text{-}Risk_{SAMA}$	$OECR_{BASE}$	$OECR_{SAMA}$
LERF-ISGTR	2.57E-07	2.35E-07	2.80E+00	2.56E+00	$32,382	$29,610
Total	3.79E-05	3.70E-05	1.14E+02	1.11E+02	$809,628	$786,928

Applying the process described in Section F.4 yields an internal events cost-risk of $16,139,784. After accounting for "round up" of the base internal events cost-risk, this value is $16,140,041. The external events contributions are accounted for by multiplying this value by 2.8:

$$\text{Total Cost-Risk}_{SAMA} = \$16,140,041 * 2.8 = \$45,192,115$$

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

SAMA 15 Averted Cost-Risk

Unit	Base Case Cost-Risk	Revised Cost-Risk	Averted Cost-Risk
Braidwood Unit 1	$46,412,800	$45,192,115	$1,220,685

There are no significant costs associated with completing the implementation of this modification and because the decision has already been made implement this change, it is not considered to be a traditional SAMA. The results are provided to document and demonstrate the estimated impact of the AFW cross-tie. However, the averted cost-risk of $1,220,685 is treated as the net value of this SAMA for this portion of the analysis.

F.6.15 SAMA 16 INSTALL HIGH FLOW SENSORS ON THE NON-ESSENTIAL SERVICE WATER SYSTEM

Installing flow sensors in the WS lines with logic to trip the pumps on high flow conditions is a potential means of terminating WS flood events before critical systems are damaged.

Assumptions:

It is assumed that this SAMA eliminates all risk associated with WS flooding scenarios.

PRA Model Changes to Model SAMA:

The cutsets were updated to delete the contributions from WS flood initiators.

Model Change(s):

The following modeling changes were made to the results cutsets:

- Event %FL1WS-GA0----T1: Event set to 0.0.
- Event %FL1WS-GT0----NA: Event set to 0.0.
- Event %FL1WSM1A0----T1: Event set to 0.0.
- Event %FL1WSM2A0----T1: Event set to 0.0.
- Event %FL1WSM3A0HVACT1: Event set to 0.0.
- Event %FL1WSM3A0----T1: Event set to 0.0.
- Event %FL1WSM3A0----T2: Event set to 0.0.
- Event %FL1WSM3A1DAFPT1: Event set to 0.0.
- Event %FL1WSM3A2DAFPT1: Event set to 0.0.
- Event %FL1WSM3A2DAFPT2: Event set to 0.0.
- Event %FL1WS-MT0----NA: Event set to 0.0.

Results of SAMA Quantification:

Implementation of this SAMA yielded a moderate reduction in internal CDF and similar reductions in Dose-Risk and Offsite Economic Cost-Risk. The results are summarized in the following table:

	Internal CDF	**Dose-Risk**	**OECR**
Base Value	3.57E-05	113.76	$809,628
SAMA Value	3.49E-05	106.99	$746,914
Percent Change	2.2%	6.0%	7.7%

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

Release Category	**$Freq._{BASE}$**	**$Freq._{SAMA}$**	**Dose-$Risk_{BASE}$**	**Dose-$Risk_{SAMA}$**	**$OECR_{BASE}$**	**$OECR_{SAMA}$**
INTACT	1.34E-05	1.34E-05	3.32E-01	3.32E-01	$300	$300
SERF-TISGTR-HLF	8.12E-09	8.12E-09	3.01E-02	3.01E-02	$229	$229
SERF-SGTR-AFW-SC	1.48E-06	1.48E-06	5.70E+00	5.70E+00	$24,716	$24,716
LATE-BMMT-AFW	6.07E-07	6.07E-07	4.03E-02	4.03E-02	$31	$31
LATE-BMMT-	9.95E-08	9.95E-08	1.90E-02	1.90E-02	$31	$31

Release Category	Freq.$_{BASE}$	Freq.$_{SAMA}$	Dose-Risk$_{BASE}$	Dose-Risk$_{SAMA}$	OECR$_{BASE}$	OECR$_{SAMA}$
NOAFW						
LATE-CHR-AFW	1.37E-05	1.35E-05	2.14E+01	2.11E+01	$45,210	$44,550
LATE-CHR-NOAFW	7.51E-06	6.82E-06	6.59E+01	5.99E+01	$642,105	$583,110
LERF-ISLOCA	3.40E-07	3.40E-07	1.55E+01	1.55E+01	$54,400	$54,400
LERF-CI	3.63E-07	3.04E-07	1.18E+00	9.88E-01	$3,775	$3,162
LERF-CFE	3.14E-08	3.06E-08	2.92E-01	2.85E-01	$2,003	$1,952
LERF-SGTR-AFW	5.92E-08	5.92E-08	5.19E-01	5.19E-01	$4,422	$4,422
LERF-SGTR-NOAFW	9.64E-10	9.64E-10	2.98E-03	2.98E-03	$24	$24
LERF-ISGTR	2.57E-07	2.38E-07	2.80E+00	2.59E+00	$32,382	$29,988
Total	3.79E-05	3.69E-05	1.14E+02	1.07E+02	$809,628	$746,914

Applying the process described in Section F.4 yields an internal events cost-risk of $15,406,821. After accounting for "round up" of the base internal events cost-risk, this value is $15,407,078. The external events contributions are accounted for by multiplying this value by 2.8:

Total Cost-Risk$_{SAMA}$ = $15,407,078 * 2.8 = $43,139,818

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

SAMA 16 Averted Cost-Risk

Unit	Base Case Cost-Risk	Revised Cost-Risk	Averted Cost-Risk
Braidwood Unit 1	$46,412,800	$43,139,818	$3,272,982

Based on a $993,800 cost of implementation for Braidwood, the net value for this SAMA is $2,279,182 ($3,272,982 - $993,800), which indicates this SAMA is potentially cost beneficial.

F.6.16 SAMA 17 USE AMASC FOR ALTERNATE LOW SG LEVEL AFW INITIATION

For non-ATWS, the AMSAC logic could be used to provide a backup initiation signal for AFW. This would mitigate failures of the normal SSPS initiation system.

Assumptions:

For this analysis, it is assumed that the AMSAC logic is 100 percent reliable and that the implementation of the SAMA can be modeled by eliminating the independent manual AFW initiation HFE in conjunction with all associated JHEPs.

PRA Model Changes to Model SAMA:

The fault tree was updated to use the existing AMSAC logic as a backup initiation signal to the AFW initiation logic.

Model Change(s):

The following HFEs were set to 0.0:

- 1AF-STARTFWHPMOA: OPERATORS FAIL TO MANUALLY START AF PUMPS FROM CR (LOFW)
- 1AF-START-BHPMOA: OPERATORS FAIL TO LOCALLY START B AUXILIARY FEEDWATER PUMP
- 1AF-START--HPMOA: OPERATORS FAIL TO MANUALLY START AF PUMPS FROM CR (NON-LOFW EVENT)
- Joint HEPs: 1RX-JHEP19-HOADA, 1RX-JHEP20-HOADA, 1RX-JHEP21-HOADA, 1RX-JHEP29-HOADA, 1RX-JHEP35-HOADA, 1RX-JHEP36-HOADA, 1RX-JHEP38-HOADA, 1RX-JHEP39-HOADA, 1RX-JHEP40-HOADA, 1RX-JHEP41-HOADA, 1RX-JHEP64-HOADA, 1RX-JHEP70-HOADA, 1RX-JHEP71-HOADA, 1RX-JHEP73-HOADA, 1RX-JHEP74-HOADA

Results of SAMA Quantification:

Implementation of this SAMA yielded a moderate reduction in internal CDF and similar reductions in Dose-Risk and Offsite Economic Cost-Risk. The results are summarized in the following table:

	Internal CDF	Dose-Risk	OECR
Base Value	3.57E-05	113.76	$809,628
SAMA Value	3.55E-05	113.68	$808,889
Percent Change	0.6%	0.1%	0.1%

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

Release Category	$Freq._{BASE}$	$Freq._{SAMA}$	$Dose\text{-}Risk_{BASE}$	$Dose\text{-}Risk_{SAMA}$	$OECR_{BASE}$	$OECR_{SAMA}$
INTACT	1.34E-05	1.34E-05	3.32E-01	3.32E-01	$300	$300
SERF-TISGTR-HLF	8.12E-09	7.38E-09	3.01E-02	2.74E-02	$229	$208
SERF-SGTR-AFW-SC	1.48E-06	1.48E-06	5.70E+00	5.70E+00	$24,716	$24,716
LATE-BMMT-AFW	6.07E-07	6.07E-07	4.03E-02	4.03E-02	$31	$31
LATE-BMMT-NOAFW	9.95E-08	9.22E-08	1.90E-02	1.76E-02	$31	$29
LATE-CHR-AFW	1.37E-05	1.37E-05	2.14E+01	2.14E+01	$45,210	$45,210
LATE-CHR-NOAFW	7.51E-06	7.51E-06	6.59E+01	6.59E+01	$642,105	$642,105
LERF-ISLOCA	3.40E-07	3.40E-07	1.55E+01	1.55E+01	$54,400	$54,400
LERF-CI	3.63E-07	3.59E-07	1.18E+00	1.17E+00	$3,775	$3,734
LERF-CFE	3.14E-08	3.07E-08	2.92E-01	2.86E-01	$2,003	$1,959
LERF-SGTR-AFW	5.92E-08	5.92E-08	5.19E-01	5.19E-01	$4,422	$4,422
LERF-SGTR-NOAFW	9.64E-10	9.64E-10	2.98E-03	2.98E-03	$24	$24
LERF-ISGTR	2.57E-07	2.52E-07	2.80E+00	2.75E+00	$32,382	$31,752
Total	3.79E-05	3.78E-05	1.14E+02	1.14E+02	$809,628	$808,889

Applying the process described in Section F.4 yields an internal events cost-risk of $16,556,798. After accounting for “round up” of the base internal events cost-risk, this value is $16,557,055. The external events contributions are accounted for by multiplying this value by 2.8:

$$\text{Total Cost-Risk}_{SAMA} = \$16{,}557{,}055 * 2.8 = \$46{,}359{,}754$$

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

SAMA 17 Averted Cost-Risk

Unit	Base Case Cost-Risk	Revised Cost-Risk	Averted Cost-Risk
Braidwood Unit 1	$46,412,800	$46,359,754	$53,046

Based on a $981,730 cost of implementation for Braidwood, the net value for this SAMA is -$928,684 ($53,046 - $981,730), which indicates this SAMA is not cost beneficial.

F.6.17 SAMA 18 AUTOMATE REFILL OF THE DIESEL DRIVEN AFW PUMP FUEL OIL DAY TANK

The action to refill the diesel driven AFW pump fuel oil day tank is currently a manual action. Level sensors in the tank could be used to control a fill valve on the gravity feed line to automate the function, which would potentially improve system reliability.

Assumptions:

For this analysis, it is assumed that the action is 100 percent reliable. Implementation of this SAMA is assumed to eliminate the independent HFE and all dependent combinations that include the action.

PRA Model Changes to Model SAMA:

The cutsets were modified by setting the action representing the failure to refill the AFW diesel fuel oil, and all JHEPs including that event, to 0.0.

Model Change(s):

The following HFEs were set to 0.0:

- 1AF01PB-FO-HXVOA: OPERATORS FAIL TO REFILL DDAFP FUEL OIL DAY TANK FROM STORAGE TANK
- Joint HEPs: 1AF01PB-FO-HXVOA, 1RX-JHEP03-HOADA, 1RX-JHEP04-HOADA, 1RX-JHEP07-HOADA, 1RX-JHEP16-HOADA, 1RX-JHEP17-HOADA, 1RX-JHEP19-HOADA, 1RX-JHEP21-HOADA, 1RX-JHEP24-HOADA, 1RX-JHEP29-HOADA, 1RX-JHEP31-HOADA , 1RX-JHEP35-HOADA, 1RX-JHEP36-HOADA, 1RX-JHEP38-HOADA, 1RX-JHEP39-HOADA, 1RX-JHEP40-HOADA, 1RX-JHEP41-HOADA, 1RX-JHEP43-HOADA, 1RX-JHEP46-HOADA, 1RX-JHEP50-HOADA, 1RX-JHEP51-HOADA, 1RX-JHEP53-HOADA, 1RX-JHEP54-HOADA, 1RX-JHEP55-HOADA, 1RX-JHEP57-HOADA, 1RX-JHEP58-HOADA, 1RX-JHEP60-HOADA, 1RX-JHEP65-HOADA, 1RX-JHEP68-HOADA, 1RX-JHEP77-HOADA, 1RX-JHEP79-HOADA , 1RX-JHEP83-HOADA

Results of SAMA Quantification:

Implementation of this SAMA yielded a moderate reduction in internal CDF and similar reductions in Dose-Risk and Offsite Economic Cost-Risk. The results are summarized in the following table:

	Internal CDF	Dose-Risk	OECR
Base Value	3.57E-05	113.76	$809,628
SAMA Value	3.53E-05	113.20	$804,143
Percent Change	1.1%	0.5%	0.7%

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

Release Category	$Freq._{BASE}$	$Freq._{SAMA}$	$Dose\text{-}Risk_{BASE}$	$Dose\text{-}Risk_{SAMA}$	$OECR_{BASE}$	$OECR_{SAMA}$
INTACT	1.34E-05	1.32E-05	3.32E-01	3.27E-01	$300	$296
SERF-TISGTR-HLF	8.12E-09	7.52E-09	3.01E-02	2.79E-02	$229	$212
SERF-SGTR-AFW-SC	1.48E-06	1.48E-06	5.70E+00	5.70E+00	$24,716	$24,716
LATE-BMMT-AFW	6.07E-07	6.07E-07	4.03E-02	4.03E-02	$31	$31
LATE-BMMT-NOAFW	9.95E-08	8.44E-08	1.90E-02	1.61E-02	$31	$26
LATE-CHR-AFW	1.37E-05	1.37E-05	2.14E+01	2.14E+01	$45,210	$45,210
LATE-CHR-NOAFW	7.51E-06	7.46E-06	6.59E+01	6.55E+01	$642,105	$637,830
LERF-ISLOCA	3.40E-07	3.40E-07	1.55E+01	1.55E+01	$54,400	$54,400
LERF-CI	3.63E-07	3.60E-07	1.18E+00	1.17E+00	$3,775	$3,744
LERF-CFE	3.14E-08	3.11E-08	2.92E-01	2.90E-01	$2,003	$1,984
LERF-SGTR-AFW	5.92E-08	5.92E-08	5.19E-01	5.19E-01	$4,422	$4,422
LERF-SGTR-NOAFW	9.64E-10	9.64E-10	2.98E-03	2.98E-03	$24	$24
LERF-ISGTR	2.57E-07	2.48E-07	2.80E+00	2.70E+00	$32,382	$31,248
Total	3.79E-05	3.76E-05	1.14E+02	1.13E+02	$809,628	$804,143

Applying the process described in Section F.4 yields an internal events cost-risk of $16,465,458. After accounting for “round up” of the base internal events cost-risk, this value is $16,465,715. The external events contributions are accounted for by multiplying this value by 2.8:

$$\text{Total Cost-Risk}_{SAMA} = \$16,465,715 * 2.8 = \$46,104,002$$

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

SAMA 18 Averted Cost-Risk

Unit	Base Case Cost-Risk	Revised Cost-Risk	Averted Cost-Risk
Braidwood Unit 1	$46,412,800	$46,104,002	$308,798

Based on a $1,608,680 cost of implementation for Braidwood, the net value for this SAMA is -$1,299,882 ($308,798 - $1,608,680), which indicates this SAMA is not cost beneficial.

F.6.18 SAMA 19 REPLACE MOVS IN THE RHR DISCHARGE LINE WITH VALVES THAT CAN ISOLATE AN ISLOCA EVENT

For cases in which the check valves fail in the RHR discharge line and an ISLOCA occurs, the event could be terminated if the containment isolation valves were capable of closing after the ISLOCA has occurred. Replacing the existing valves (MOVs _SI8809A, _SI8809B, and _SI8840) with an alternate design could provide this capability.

Assumptions:

It is assumed that implementation of this SAMA will eliminate all risk from the ISLOCA events occurring in the RHR discharge lines

PRA Model Changes to Model SAMA:

The cutsets were modified by setting the events representing ISLOCAs in the RHR discharge line to 0.0. The following event was set to 0.0:

- %RCS-RHR-DISCHIE: FREQ OF EXPOSING RHR PUMP DISCHARGE HEADERS TO RCS PRESSURE

Results of SAMA Quantification:

Implementation of this SAMA yielded a moderate reduction in internal CDF and similar reductions in Dose-Risk and Offsite Economic Cost-Risk. The results are summarized in the following table:

	Internal CDF	Dose-Risk	OECR
Base Value	3.57E-05	113.76	$809,628
SAMA Value	3.54E-05	101.99	$768,396
Percent Change	0.8%	10.4%	5.1%

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

Release Category	$Freq._{BASE}$	$Freq._{SAMA}$	$Dose\text{-}Risk_{BASE}$	$Dose\text{-}Risk_{SAMA}$	$OECR_{BASE}$	$OECR_{SAMA}$
INTACT	1.34E-05	1.34E-05	3.32E-01	3.32E-01	$300	$300
SERF-TISGTR-HLF	8.12E-09	8.12E-09	3.01E-02	3.01E-02	$229	$229
SERF-SGTR-AFW-SC	1.48E-06	1.48E-06	5.70E+00	5.70E+00	$24,716	$24,716
LATE-BMMT-AFW	6.07E-07	6.07E-07	4.03E-02	4.03E-02	$31	$31
LATE-BMMT-NOAFW	9.95E-08	9.95E-08	1.90E-02	1.90E-02	$31	$31
LATE-CHR-AFW	1.37E-05	1.37E-05	2.14E+01	2.14E+01	$45,210	$45,210
LATE-CHR-NOAFW	7.51E-06	7.51E-06	6.59E+01	6.59E+01	$642,105	$642,105
LERF-ISLOCA	3.40E-07	8.23E-08	1.55E+01	3.76E+00	$54,400	$13,168
LERF-CI	3.63E-07	3.63E-07	1.18E+00	1.18E+00	$3,775	$3,775
LERF-CFE	3.14E-08	3.14E-08	2.92E-01	2.92E-01	$2,003	$2,003
LERF-SGTR-AFW	5.92E-08	5.92E-08	5.19E-01	5.19E-01	$4,422	$4,422
LERF-SGTR-NOAFW	9.64E-10	9.64E-10	2.98E-03	2.98E-03	$24	$24
LERF-ISGTR	2.57E-07	2.57E-07	2.80E+00	2.80E+00	$32,382	$32,382
Total	3.79E-05	3.76E-05	1.14E+02	1.02E+02	$809,628	$768,396

Applying the process described in Section F.4 yields an internal events cost-risk of $15,593,177. After accounting for “round up” of the base internal events cost-risk, this value is $15,593,434. The external events contributions are accounted for by multiplying this value by 2.8:

$$\text{Total Cost-Risk}_{SAMA} = \$15{,}593{,}434 * 2.8 = \$43{,}661{,}615$$

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

SAMA 19 Averted Cost-Risk

Unit	Base Case Cost-Risk	Revised Cost-Risk	Averted Cost-Risk
Braidwood Unit 1	$46,412,800	$43,661,615	$2,751,185

Based on a $900,000 cost of implementation for Braidwood, the net value for this SAMA is $1,851,185 ($2,751,185 - $900,000), which indicates this SAMA is potentially cost beneficial.

F.6.19 SAMA 20 DISALLOW ON-LINE RHR HX MAINTENANCE

For cases in which one train of RHR is out of service for maintenance in such a way that it cannot respond in an accident scenario, the plant is vulnerable to single failure events for certain initiating events that require heat removal (for example LOCAs). Preventing on-line maintenance of RHR would significantly reduce the frequency of the associated core damage scenarios.

Assumptions:

It is assumed that implementation of this SAMA will eliminate all risk associated with RHR maintenance (no assessment is made to account for any increase in shutdown risk related to performing the maintenance during an outage).

PRA Model Changes to Model SAMA:

The cutsets were modified by setting the events representing RHR maintenance line to 0.0.

Model Change(s):

The following events were set to 0.0:

- 1RH01PA-----PMMM: RH PUMP 1RH01PA UNAVAILABLE DUE TO MAINTENANCE
- 1RH01PB-----PMMM: RH PUMP 1RH01PB UNAVAILABLE DUE TO MAINTENANCE

Results of SAMA Quantification:

Implementation of this SAMA yielded a moderate reduction in internal CDF and similar reductions in Dose-Risk and Offsite Economic Cost-Risk. The results are summarized in the following table:

	Internal CDF	Dose-Risk	OECR
Base Value	3.57E-05	113.76	$809,628
SAMA Value	3.54E-05	113.71	$809,194
Percent Change	0.8%	0.0%	0.1%

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

Release Category	$Freq._{BASE}$	$Freq._{SAMA}$	$Dose\text{-}Risk_{BASE}$	$Dose\text{-}Risk_{SAMA}$	$OECR_{BASE}$	$OECR_{SAMA}$
INTACT	1.34E-05	1.31E-05	3.32E-01	3.25E-01	$300	$293
SERF-TISGTR-HLF	8.12E-09	7.93E-09	3.01E-02	2.94E-02	$229	$224
SERF-SGTR-AFW-SC	1.48E-06	1.48E-06	5.70E+00	5.70E+00	$24,716	$24,716
LATE-BMMT-AFW	6.07E-07	5.99E-07	4.03E-02	3.98E-02	$31	$30
LATE-BMMT-NOAFW	9.95E-08	9.17E-08	1.90E-02	1.75E-02	$31	$28
LATE-CHR-AFW	1.37E-05	1.37E-05	2.14E+01	2.14E+01	$45,210	$45,210
LATE-CHR-NOAFW	7.51E-06	7.51E-06	6.59E+01	6.59E+01	$642,105	$642,105
LERF-ISLOCA	3.40E-07	3.40E-07	1.55E+01	1.55E+01	$54,400	$54,400
LERF-CI	3.63E-07	3.61E-07	1.18E+00	1.17E+00	$3,775	$3,754
LERF-CFE	3.14E-08	3.12E-08	2.92E-01	2.90E-01	$2,003	$1,991
LERF-SGTR-AFW	5.92E-08	5.91E-08	5.19E-01	5.18E-01	$4,422	$4,415
LERF-SGTR-NOAFW	9.64E-10	9.64E-10	2.98E-03	2.98E-03	$24	$24
LERF-ISGTR	2.57E-07	2.54E-07	2.80E+00	2.77E+00	$32,382	$32,004
Total	3.79E-05	3.75E-05	1.14E+02	1.14E+02	$809,628	$809,194

Applying the process described in Section F.4 yields an internal events cost-risk of $16,559,438. After accounting for "round up" of the base internal events cost-risk, this value is $16,559,695. The external events contributions are accounted for by multiplying this value by 2.8:

$$\text{Total Cost-Risk}_{SAMA} = \$16,559,695 * 2.8 = \$46,367,146$$

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

SAMA 20 Averted Cost-Risk

Unit	Base Case Cost-Risk	Revised Cost-Risk	Averted Cost-Risk
Braidwood Unit 1	$46,412,800	$46,367,146	$45,654

Based on a $20,000,000 cost of implementation for Braidwood, the net value for this SAMA is -$19,954,346 ($45,654- $20,000,000), which indicates this SAMA is not cost beneficial.

F.6.20 SAMA 21 INSTALL AN EMERGENCY ISOLATION VALVE IN EACH OF THE RHR SUCTION LINES

For cases in which the two motor operated isolation valves in the RHR suction line fail and result in the overpressurization of the low pressure RHR piping, a LOCA outside containment can occur if the RHR piping breaks. In the event of a piping break, having an additional, normally open MOV located on the high pressure piping capable of closing against RCS pressure would provide a means of terminating the ISLOCA event.

Assumptions:

It is assumed that implementation of this SAMA will eliminate all risk from the ISLOCA events occurring in the RHR suction lines

PRA Model Changes to Model SAMA:

The cutsets were modified by setting the events representing ISLOCAs in the RHR suction lines to 0.0.

Model Change(s):

The following event was set to 0.0:

- %RCS-RHR-SUCT-IE: FREQUENCY OF HAVING RCS PRESSURE IN THE RHR SUCTION LINE

Results of SAMA Quantification:

Implementation of this SAMA yielded a moderate reduction in internal CDF and similar reductions in Dose-Risk and Offsite Economic Cost-Risk. The results are summarized in the following table:

	Internal CDF	Dose-Risk	OECR
Base Value	3.57E-05	113.76	$809,628
SAMA Value	3.56E-05	110.79	$799,228
Percent Change	0.3%	2.6%	1.3%

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

Release Category	$Freq._{BASE}$	$Freq._{SAMA}$	$Dose\text{-}Risk_{BASE}$	$Dose\text{-}Risk_{SAMA}$	$OECR_{BASE}$	$OECR_{SAMA}$
INTACT	1.34E-05	1.34E-05	3.32E-01	3.32E-01	$300	$300
SERF-TISGTR-HLF	8.12E-09	8.12E-09	3.01E-02	3.01E-02	$229	$229
SERF-SGTR-AFW-SC	1.48E-06	1.48E-06	5.70E+00	5.70E+00	$24,716	$24,716
LATE-BMMT-AFW	6.07E-07	6.07E-07	4.03E-02	4.03E-02	$31	$31
LATE-BMMT-NOAFW	9.95E-08	9.95E-08	1.90E-02	1.90E-02	$31	$31
LATE-CHR-AFW	1.37E-05	1.37E-05	2.14E+01	2.14E+01	$45,210	$45,210
LATE-CHR-NOAFW	7.51E-06	7.51E-06	6.59E+01	6.59E+01	$642,105	$642,105
LERF-ISLOCA	3.40E-07	2.75E-07	1.55E+01	1.26E+01	$54,400	$44,000
LERF-CI	3.63E-07	3.63E-07	1.18E+00	1.18E+00	$3,775	$3,775
LERF-CFE	3.14E-08	3.14E-08	2.92E-01	2.92E-01	$2,003	$2,003
LERF-SGTR-AFW	5.92E-08	5.92E-08	5.19E-01	5.19E-01	$4,422	$4,422
LERF-SGTR-NOAFW	9.64E-10	9.64E-10	2.98E-03	2.98E-03	$24	$24
LERF-ISGTR	2.57E-07	2.57E-07	2.80E+00	2.80E+00	$32,382	$32,382
Total	3.79E-05	3.78E-05	1.14E+02	1.11E+02	$809,628	$799,228

Applying the process described in Section F.4 yields an internal events cost-risk of $16,327,244. After accounting for “round up” of the base internal events cost-risk, this value is $16,327,501. The external events contributions are accounted for by multiplying this value by 2.8:

$$\text{Total Cost-Risk}_{\text{SAMA}} = \$16{,}327{,}501 * 2.8 = \$45{,}717{,}003$$

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

SAMA 21 Averted Cost-Risk

Unit	Base Case Cost-Risk	Revised Cost-Risk	Averted Cost-Risk
Braidwood Unit 1	$46,412,800	$45,717,003	$695,797

Based on an $1,600,000 cost of implementation for Braidwood, the net value for this SAMA is -$904,203 ($695,797 - $1,600,000), which indicates this SAMA is not cost beneficial.

F.6.21 SAMA 22 INSTALL THE SAME HIGH FLOW ISOLATION LOGIC USED ON VALVE _CC685 ON VALVE _CC9438

In the event that an RCP Thermal Barrier Cooling heat exchangers breaks, the current in-containment relief valves are designed to relieve pressure at 2485 psig, which would be within the capacity of the piping up to the isolation boundary. However, if the Thermal Barrier Cooling Hx were to break and the isolation valve failed to close, the CC system could be over pressurized and inventory could be transferred outside containment through the 150 psid relief valves. A potential means of mitigating this event would be to install the same isolation logic used on valve _CC685 on valve_CC9438.

Assumptions:

It is assumed that implementation of this SAMA will eliminate all risk from the ISLOCA events occurring in the RCP thermal barrier cooling heat exchangers.

PRA Model Changes to Model SAMA:

The cutsets were modified by setting the events representing ISLOCAs in the RCP thermal barrier cooling heat exchangers to 0.0.

Model Change(s):

The following event was set to 0.0:

- %RCP-HX-RUPT--IE: FREQUENCY OF RCP HEAT EXCHANGER RUPTURE

Results of SAMA Quantification:

Implementation of this SAMA yielded a moderate reduction in internal CDF and similar reductions in Dose-Risk and Offsite Economic Cost-Risk. The results are summarized in the following table:

	Internal CDF	Dose-Risk	OECR
Base Value	3.57E-05	113.76	$809,628
SAMA Value	3.57E-05	113.08	$807,228
Percent Change	0.0%	0.6%	0.3%

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

Release Category	$Freq._{BASE}$	$Freq._{SAMA}$	$Dose\text{-}Risk_{BASE}$	$Dose\text{-}Risk_{SAMA}$	$OECR_{BASE}$	$OECR_{SAMA}$
INTACT	1.34E-05	1.34E-05	3.32E-01	3.32E-01	$300	$300
SERF-TISGTR-HLF	8.12E-09	8.12E-09	3.01E-02	3.01E-02	$229	$229
SERF-SGTR-AFW-SC	1.48E-06	1.48E-06	5.70E+00	5.70E+00	$24,716	$24,716
LATE-BMMT-AFW	6.07E-07	6.07E-07	4.03E-02	4.03E-02	$31	$31
LATE-BMMT-NOAFW	9.95E-08	9.95E-08	1.90E-02	1.90E-02	$31	$31
LATE-CHR-AFW	1.37E-05	1.37E-05	2.14E+01	2.14E+01	$45,210	$45,210
LATE-CHR-NOAFW	7.51E-06	7.51E-06	6.59E+01	6.59E+01	$642,105	$642,105
LERF-ISLOCA	3.40E-07	3.25E-07	1.55E+01	1.49E+01	$54,400	$52,000
LERF-CI	3.63E-07	3.63E-07	1.18E+00	1.18E+00	$3,775	$3,775
LERF-CFE	3.14E-08	3.14E-08	2.92E-01	2.92E-01	$2,003	$2,003
LERF-SGTR-AFW	5.92E-08	5.92E-08	5.19E-01	5.19E-01	$4,422	$4,422
LERF-SGTR-NOAFW	9.64E-10	9.64E-10	2.98E-03	2.98E-03	$24	$24
LERF-ISGTR	2.57E-07	2.57E-07	2.80E+00	2.80E+00	$32,382	$32,382
Total	3.79E-05	3.78E-05	1.14E+02	1.13E+02	$809,628	$807,228

Applying the process described in Section F.4 yields an internal events cost-risk of $16,519,029. After accounting for "round up" of the base internal events cost-risk, this value is $16,519,286. The external events contributions are accounted for by multiplying this value by 2.8:

$$\text{Total Cost-Risk}_{SAMA} = \$16{,}519{,}286 * 2.8 = \$46{,}254{,}001$$

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

SAMA 22 Averted Cost-Risk

Unit	Base Case Cost-Risk	Revised Cost-Risk	Averted Cost-Risk
Braidwood Unit 1	$46,412,800	$46,254,001	$158,799

Based on a $250,000 cost of implementation for Braidwood, the net value for this SAMA is -$91,201 ($158,799 - $250,000), which indicates this SAMA is not cost beneficial.

F.6.22 SAMA 23 INSTALL A PASSIVE HYDROGEN IGNITION SYSTEM

For accident scenarios resulting in the generation of hydrogen in quantities sufficient to cause significant hydrogen detonations, containment failure is possible. A potential means of preventing these containment failure scenarios would be to install a passive hydrogen ignition system.

Assumptions:

It is assumed that implementation of this SAMA will eliminate all containment failures due to hydrogen detonation. Some of the Level 2 events that represent containment failure due to hydrogen detonations also include containment failure due to other phenomena, but no attempt is made to separate them from the hydrogen failures. This results in an increased averted cost-risk, which makes it more likely that the SAMA will be cost effective.

PRA Model Changes to Model SAMA:

The cutsets were modified by setting the events representing containment failure due to hydrogen detonation to 0.0.

Model Change(s):

The following events were set to 0.0:

- 1L2-CNT-VF-CFE1: Early Cont Failure due to Hydrogen Burn or Stm Expl
- 1L2-CNT-VF-CFE2: Early Cont Failure due to Hydrogen Burn
- 1L2-CNT-VF-CFE4: Early Cont Failure due to Direct Containment Heating, Hydrogen Burn, or Stm Expl

Results of SAMA Quantification:

Implementation of this SAMA yielded a moderate reduction in internal CDF and similar reductions in Dose-Risk and Offsite Economic Cost-Risk. The results are summarized in the following table:

	Internal CDF	Dose-Risk	OECR
Base Value	3.57E-05	113.76	$809,628
SAMA Value	3.57E-05	113.47	$807,625
Percent Change	0.0%	0.3%	0.2%

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

Release Category	$Freq._{BASE}$	$Freq._{SAMA}$	$Dose\text{-}Risk_{BASE}$	$Dose\text{-}Risk_{SAMA}$	$OECR_{BASE}$	$OECR_{SAMA}$
INTACT	1.34E-05	1.34E-05	3.32E-01	3.32E-01	$300	$300
SERF-TISGTR-HLF	8.12E-09	8.12E-09	3.01E-02	3.01E-02	$229	$229
SERF-SGTR-AFW-SC	1.48E-06	1.48E-06	5.70E+00	5.70E+00	$24,716	$24,716
LATE-BMMT-AFW	6.07E-07	6.07E-07	4.03E-02	4.03E-02	$31	$31
LATE-BMMT-NOAFW	9.95E-08	9.95E-08	1.90E-02	1.90E-02	$31	$31
LATE-CHR-AFW	1.37E-05	1.37E-05	2.14E+01	2.14E+01	$45,210	$45,210
LATE-CHR-NOAFW	7.51E-06	7.51E-06	6.59E+01	6.59E+01	$642,105	$642,105
LERF-ISLOCA	3.40E-07	3.40E-07	1.55E+01	1.55E+01	$54,400	$54,400
LERF-CI	3.63E-07	3.63E-07	1.18E+00	1.18E+00	$3,775	$3,775
LERF-CFE	3.14E-08	0.00E+00	2.92E-01	0.00E+00	$2,003	$0
LERF-SGTR-AFW	5.92E-08	5.92E-08	5.19E-01	5.19E-01	$4,422	$4,422

Release Category	$Freq._{BASE}$	$Freq._{SAMA}$	$Dose\text{-}Risk_{BASE}$	$Dose\text{-}Risk_{SAMA}$	$OECR_{BASE}$	$OECR_{SAMA}$
LERF-SGTR-NOAFW	9.64E-10	9.64E-10	2.98E-03	2.98E-03	$24	$24
LERF-ISGTR	2.57E-07	2.57E-07	2.80E+00	2.80E+00	$32,382	$32,382
Total	3.79E-05	3.78E-05	1.14E+02	1.13E+02	$809,628	$807,625

Applying the process described in Section F.4 yields an internal events cost-risk of $16,536,821. After accounting for "round up" of the base internal events cost-risk, this value is $16,537,078. The external events contributions are accounted for by multiplying this value by 2.8:

$$\text{Total Cost-Risk}_{SAMA} = \$16,537,078 * 2.8 = \$46,303,818$$

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

SAMA 23 Averted Cost-Risk

Unit	Base Case Cost-Risk	Revised Cost-Risk	Averted Cost-Risk
Braidwood Unit 1	$46,412,800	$46,303,818	$108,982

Based on a $760,000 cost of implementation for Braidwood, the net value for this SAMA is -$651,018 ($108,982 - $760,000), which indicates this SAMA is not cost beneficial.

F.6.23 SAMA 24 PROVIDE A REACTOR VESSEL EXTERIOR COOLING SYSTEM

This SAMA would provide the potential to cool a molten core before it causes vessel failure, if the lower head can be submerged in water. For Braidwood, use of existing emergency power is adequate to address the highest contributors.

Assumptions:

It is assumed that the implementation of this SAMA is 100 percent effective at preventing relocation of the core to the containment floor. For cases in which containment heat removal is successful, this would result in the reclassification of the basemat melt through scenarios as "intact" cases.

For containment overpressure failure cases, this SAMA would result in the retention of the core in the vessel without an overlying pool of water. The dominant scenarios for the existing containment overpressure failure cases are those in which containment spray is available and water is transferred to the containment floor. In these scenarios, use of the exterior vessel cooling system could actually prevent scrubbing of the release; however, for simplicity, the benefit of this SAMA is not reduced to address the fact that this SAMA would eliminate the scrubbing mechanism for these scenarios. This assumption increases this SAMA's averted cost-risk.

With the exception of hydrogen detonation, the early containment failure modes are linked to reactor vessel failure such that early containment failure would likely be avoided if reactor vessel failure is prevented. For simplicity, it is assumed that this SAMA eliminates all early containment failures.

PRA Model Changes to Model SAMA:

The events in the PRA model associated with early containment failure and basemat failure have been set to 0.0.

Model Change(s):

The following event probability changes were made to the PRA model:

- 1L2-CNT-VF-CFE1: Early Cont Failure due to Hydrogen Burn or Stm Expl, set to 0.0.
- 1L2-CNT-VF-CFE2: Early Cont Failure due to Hydrogen Burn, set to 0.0.
- 1L2-CNT-VF-CFE3: Early Cont Failure due to Direct Containment Heating, set to 0.0
- 1L2-CNT-VF-CFE4: Early Cont Failure due to Direct Containment Heating, Hydrogen Burn, or Stm Expl, set to 0.0.
- 1L2-CNT-VF-BMMTD: Probability of BMMT with a dry cavity, set to 0.0.
- 1L2-CNT-VF-BMMTW: Probability of BMMT with water in the cavity, set to 0.0.

Results of SAMA Quantification:

Implementation of this SAMA yielded a moderate reduction in internal CDF and similar reductions in Dose-Risk and Offsite Economic Cost-Risk. The results are summarized in the following table:

	Internal CDF	**Dose-Risk**	**OECR**
Base Value	3.57E-05	113.76	$809,628
SAMA Value	3.57E-05	113.41	$807,563
Percent Change	0.0%	0.3%	0.3%

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

Release Category	$Freq._{BASE}$	$Freq._{SAMA}$	$Dose\text{-}Risk_{BASE}$	$Dose\text{-}Risk_{SAMA}$	$OECR_{BASE}$	$OECR_{SAMA}$
INTACT	1.34E-05	1.34E-05	3.32E-01	3.32E-01	$300	$300
SERF-TISGTR-HLF	8.12E-09	8.12E-09	3.01E-02	3.01E-02	$229	$229
SERF-SGTR-AFW-SC	1.48E-06	1.48E-06	5.70E+00	5.70E+00	$24,716	$24,716
LATE-BMMT-AFW	6.07E-07	0.00E+00	4.03E-02	0.00E+00	$31	$0
LATE-BMMT-NOAFW	9.95E-08	0.00E+00	1.90E-02	0.00E+00	$31	$0
LATE-CHR-AFW	1.37E-05	1.37E-05	2.14E+01	2.14E+01	$45,210	$45,210
LATE-CHR-NOAFW	7.51E-06	7.51E-06	6.59E+01	6.59E+01	$642,105	$642,105
LERF-ISLOCA	3.40E-07	3.40E-07	1.55E+01	1.55E+01	$54,400	$54,400
LERF-CI	3.63E-07	3.63E-07	1.18E+00	1.18E+00	$3,775	$3,775
LERF-CFE	3.14E-08	0.00E+00	2.92E-01	0.00E+00	$2,003	$0
LERF-SGTR-AFW	5.92E-08	5.92E-08	5.19E-01	5.19E-01	$4,422	$4,422
LERF-SGTR-NOAFW	9.64E-10	9.64E-10	2.98E-03	2.98E-03	$24	$24
LERF-ISGTR	2.57E-07	2.57E-07	2.80E+00	2.80E+00	$32,382	$32,382
Total	3.79E-05	3.71E-05	1.14E+02	1.13E+02	$809,628	$807,563

Applying the process described in Section F.4 yields an internal events cost-risk of $16,534,109. After accounting for “round up” of the base internal events cost-risk, this value is $16,534,366. The external events contributions are accounted for by multiplying this value by 2.8:

$$\text{Total Cost-Risk}_{SAMA} = \$16{,}534{,}366 * 2.8 = \$46{,}296{,}225$$

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

SAMA 24 Averted Cost-Risk

Unit	Base Case Cost-Risk	Revised Cost-Risk	Averted Cost-Risk
Braidwood Unit 1	$46,412,800	$46,296,225	$116,575

Based on a $1,250,000 cost of implementation for Braidwood, the net value for this SAMA is -$1,133,425 ($116,575 - $1,250,000), which indicates this SAMA is not cost beneficial.

F.6.24 SAMA 25 INSTALL A FILTERED CONTAINMENT VENT

This SAMA would provide a means of preventing long term containment overpressure failures by relieving pressure through a scrubbed release path. While post core damage venting is undesirable, a controlled scrubbed release is preferable to an un-scrubbed release through a containment break.

Assumptions:

It is assumed that this SAMA is 100 percent reliable in operation, but the effectiveness of the radionuclide scrubbing mechanism is not complete. For this analysis, it is assumed that the filtered vent reduces the consequential dose and offsite economic cost associated with containment overpressure failures by a factor of 10.

PRA Model Changes to Model SAMA:

The results of the Level 3 model (dose, offsite economic cost) for the LATE-CHR-AFW and LATE-CHR-NOAFW endstates are reduced by a factor of 10.

Model Change(s):

The following changes were made to the L3 results:

- LATE-CHR-AFW: Dose-risk and OECR multiplied by 0.1.
- LATE-CHR-NOAFW: Dose-risk and OECR multiplied by 0.1.

Results of SAMA Quantification:

Implementation of this SAMA yielded a moderate reduction in internal CDF and similar reductions in Dose-Risk and Offsite Economic Cost-Risk. The results are summarized in the following table:

	Internal CDF	Dose-Risk	OECR
Base Value	3.57E-05	113.76	$809,628
SAMA Value	3.57E-05	35.18	$191,045
Percent Change	0.0%	69.1%	76.4%

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

Release Category	$Freq._{BASE}$	$Freq._{SAMA}$	$Dose\text{-}Risk_{BASE}$	$Dose\text{-}Risk_{SAMA}$	$OECR_{BASE}$	$OECR_{SAMA}$
INTACT	1.34E-05	1.34E-05	3.32E-01	3.32E-01	$300	$300
SERF-TISGTR-HLF	8.12E-09	8.12E-09	3.01E-02	3.01E-02	$229	$229
SERF-SGTR-AFW-SC	1.48E-06	1.48E-06	5.70E+00	5.70E+00	$24,716	$24,716
LATE-BMMT-AFW	6.07E-07	6.07E-07	4.03E-02	4.03E-02	$31	$31
LATE-BMMT-NOAFW	9.95E-08	9.95E-08	1.90E-02	1.90E-02	$31	$31
LATE-CHR-AFW	1.37E-05	1.37E-05	2.14E+01	2.14E+00	$45,210	$4,521
LATE-CHR-NOAFW	7.51E-06	7.51E-06	6.59E+01	6.59E+00	$642,105	$64,211
LERF-ISLOCA	3.40E-07	3.40E-07	1.55E+01	1.55E+01	$54,400	$54,400
LERF-CI	3.63E-07	3.63E-07	1.18E+00	1.18E+00	$3,775	$3,775
LERF-CFE	3.14E-08	3.14E-08	2.92E-01	2.92E-01	$2,003	$2,003
LERF-SGTR-AFW	5.92E-08	5.92E-08	5.19E-01	5.19E-01	$4,422	$4,422
LERF-SGTR-NOAFW	9.64E-10	9.64E-10	2.98E-03	2.98E-03	$24	$24
LERF-ISGTR	2.57E-07	2.57E-07	2.80E+00	2.80E+00	$32,382	$32,382
Total	3.79E-05	3.79E-05	1.14E+02	3.52E+01	$809,628	$191,045

Applying the process described in Section F.4 yields an internal events cost-risk of $4,908,897. After accounting for “round up” of the base internal events cost-risk, this value is $4,909,154. The external events contributions are accounted for by multiplying this value by 2.8:

$$\text{Total Cost-Risk}_{SAMA} = \$4,909,154 * 2.8 = \$13,745,631$$

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

SAMA 25 Averted Cost-Risk

Unit	Base Case Cost-Risk	Revised Cost-Risk	Averted Cost-Risk
Braidwood Unit 1	$46,412,800	$13,745,631	$32,667,169

Based on a $5,700,000 cost of implementation for Braidwood, the net value for this SAMA is $26,967,169 ($32,667,169 - $5,700,000), which indicates this SAMA is potentially cost beneficial.

F.6.25 SAMA 26 DMS USING A DEDICATED GENERATOR, SELF COOLED CHARGING PUMP, AND A PORTABLE AFW PUMP

This SAMA represents an alternate configuration of the DMS in which seal LOCAs are prevented using a seal injection system rather than by “no leak” seals. A dedicated 480V AC generator is proposed as a means of supporting long term SG makeup by maintaining the buses used for the battery chargers for SG level instrumentation and for powering a self-cooled primary side seal injection pump. A portable, engine driven SG makeup pump would provide an alternate means of SG makeup, with injection connections available on different divisions. Fire protection should provide both CST makeup and a suction source connection for the portable SG makeup pump A means of providing borated makeup to the RWST is also required, which could potentially be performed using the fire protection system and an eductor. Finally, a connection point to an outside source would have to be provided for the containment spray system for long term spray capability in an SBO.

Assumptions:

SAMA 26 was generally identified as a means of mitigating scenarios in which loss of SG makeup is a slowly developing evolution, such as in SBO events where battery depletion eventually fails AFW or in loss of SX cases in which the AFW pumps may be able to run for some time before failure. No credit is taken for the DMS in LOCA (other than seal LOCA) or ATWS scenarios. The DMS is credited in SGTR initiators as most cases include success of injection where time would be available to recover secondary side heat removal in the event of an initial AFW failure. Prior to core damage, activity levels are expected to be low enough to perform any alignment required.

The DMS capabilities are assumed to be represented by indefinite AFW makeup capability and by an alternate high pressure injection function capable of providing alternate seal injection to prevent RCP seal LOCAs. The current PRA does not include credit for RWST refill, so the PRA is structured to require recirculation mode in seal LOCA evolutions even with AFW success. This SAMA, however, includes an RWST makeup capability that is assumed to preclude the need for recirculation mode. Long term containment overfill is potentially an issue that could ultimately prevent success in these cases, but it is assumed that a success of DMS seal injection and SG makeup results in a successful endstate. In order to simplify the modeling process, the seal LOCA flag is used to model the impact of the DMS seal injection system. The self-cooled charging pump is assumed to reduce the frequency of seal LOCA sequences by a factor of 100.

The AFW makeup capability includes alignment and control of a dedicated (permanently installed) 480V generator and alignment and control of a portable SG makeup pump. A new event with a failure probability of 1E-2 is used for this function.

It is assumed that the cognitive failure to diagnose the need for secondary cooling (1FW-FRH1---HSGOA), which is related to the AFW X-tie, FW restoration, and bleed and feed, will also fail the DMS. In addition, any dependent combinations are also assumed to fail the DMS.

PRA Model Changes to Model SAMA:

The capabilities of SAMA 26 are essentially the same as those for SAMA 11 with the exception that the seal LOCAs are mitigated by an injection capability rather than prevented by an alternate seal design. The impact of the seal injection system is modeled by manipulating the cutsets from SAMA 11.

Model Change(s):

The cutsets from SAMA 11 were modified to reflect the use of the DMS primary injection capability for Seal LOCA mitigation.

The following modeling changes were made to the SAMA 11 cutsets:

- The FLAG-SEAL-LOCA flag was replaced by event 1DMS (as defined in SAMA 11) to represent the use of the DMS to mitigate Seal LOCAs.
- To address potential dependency issues, the 1DMS event was replaced by event 1DMS-DEPENDENT (set to 1.0) for any cutsets including failure to diagnose the need for feed and bleed (represents complete cognitive dependence between feed and bleed and primary side injection with the DMS). The HFEs addressed included 1FW-FRH1---HSGOA, 1RX-JHEP03-HOADA and similar events for the following JHEP combinations: 07, 09, 11,12, 14, 17, 21, 24, 25, 27, 39, 49, 50, 54, 58, 64, 74, and 80.

Results of SAMA Quantification:

Implementation of this SAMA yielded a moderate reduction in internal CDF and similar reductions in Dose-Risk and Offsite Economic Cost-Risk. The results are summarized in the following table:

	Internal CDF	**Dose-Risk**	**OECR**
Base Value	3.57E-05	113.76	$809,628
SAMA Value	1.11E-05	26.77	$127,000
Percent Change	68.9%	76.5%	84.3%

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

Release Category	**$Freq._{BASE}$**	**$Freq._{SAMA}$**	**$Dose\text{-}Risk_{BASE}$**	**$Dose\text{-}Risk_{SAMA}$**	**$OECR_{BASE}$**	**$OECR_{SAMA}$**
INTACT	1.34E-05	8.77E-06	3.32E-01	2.17E-01	$300	$196
SERF-TISGTR-HLF	8.12E-09	1.95E-09	3.01E-02	7.23E-03	$229	$55
SERF-SGTR-AFW-SC	1.48E-06	1.48E-06	5.70E+00	5.70E+00	$24,716	$24,716
LATE-BMMT-AFW	6.07E-07	4.06E-07	4.03E-02	2.70E-02	$31	$21
LATE-BMMT-NOAFW	9.95E-08	4.45E-08	1.90E-02	8.50E-03	$31	$14
LATE-CHR-AFW	1.37E-05	1.48E-07	2.14E+01	2.31E-01	$45,210	$488
LATE-CHR-NOAFW	7.51E-06	4.29E-07	6.59E+01	3.77E+00	$642,105	$36,680
LERF-ISLOCA	3.40E-07	3.40E-07	1.55E+01	1.55E+01	$54,400	$54,400
LERF-CI	3.63E-07	8.77E-08	1.18E+00	2.85E-01	$3,775	$912
LERF-CFE	3.14E-08	9.20E-09	2.92E-01	8.57E-02	$2,003	$587
LERF-SGTR-AFW	5.92E-08	5.92E-08	5.19E-01	5.19E-01	$4,422	$4,422
LERF-SGTR-NOAFW	9.64E-10	9.64E-10	2.98E-03	2.98E-03	$24	$24
LERF-ISGTR	2.57E-07	3.56E-08	2.80E+00	3.88E-01	$32,382	$4,486
Total	3.79E-05	1.18E-05	1.14E+02	2.68E+01	$809,628	$127,000

Applying the process described in Section F.4 yields an internal events cost-risk of $3,019,259. After accounting for “round up” of the base internal events cost-risk, this value is $3,019,516. The external events contributions are accounted for by multiplying this value by 2.8:

$$\text{Total Cost-Risk}_{SAMA} = \$3{,}019{,}516 * 2.8 = \$8{,}454{,}645$$

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

SAMA 26 Averted Cost-Risk

Unit	Base Case Cost-Risk	Revised Cost-Risk	Averted Cost-Risk
Braidwood Unit 1	$46,412,800	$8,454,645	$37,958,155

Based on a $2,400,000 cost of implementation for Braidwood, the net value for this SAMA is $35,558,155 ($37,958,155 - $2,400,000), which indicates this SAMA is potentially cost beneficial.

F.6.26 SAMA 27 PROTECT RH, SI, AND CVCS CUBICLE COOLING FAN CABLES IN FIRE ZONE 11.3-0

While most of the equipment damage in the dominant fire scenario in zone 11.3-0 is related to the loss of MCC 132X1 (the ignition source), protecting the cables related to the RH, SI, and CVCS pump cubicle cooling fans may reduce the likelihood that room cooling will be failed for those pumps.

Assumptions:

This SAMA will eliminate all of the risk associated with fire zone 11.3-0.

The ratio of internal events cost-risk to internal events CDF is equal to the ratio of fire cost-risk to fire CDF.

PRA Model Changes to Model SAMA:

The CDF associated with fire zone 11.3-0 was changed from 5.66E-06 to 0.0 to model the installation of the cable protection.

Results of SAMA Quantification:

The averted cost-risk for this SAMA is the cost-risk associated with fire zone 11.3-0 because this SAMA is assumed to entirely eliminate it. Using the assumptions identified above, the result is as follows:

$16,575,743 / 3.57E-05 * 5.66E-06 = $2,627,975

Based on a $975,000 cost of implementation for Braidwood, the net value for this SAMA is $1,652,975 ($2,627,975 - $975,000), which indicates this SAMA is potentially cost beneficial.

F.6.27 SAMA 28 INSTALL FIRE BARRIERS AROUND MCC 132X4

Fires that start in this MCC are exacerbated by the propagation of the fire to nearby equipment. Installation of fire barriers to protect the equipment could mitigate the consequences of the fires.

Assumptions:

This SAMA will eliminate all of the risk associated with fire zone 11.6-1.

The ratio of internal events cost-risk to internal events CDF is equal to the ratio of fire cost-risk to fire CDF.

PRA Model Changes to Model SAMA:

The CDF associated with fire zone 11.6-1 was changed from 3.68E-06 to 0.0 to model the installation of the fire barriers.

Results of SAMA Quantification:

The averted cost-risk for this SAMA is the cost-risk associated with fire zone 11.6-1 because this SAMA is assumed to entirely eliminate it. Using the assumptions identified above, the result is as follows:

$16,575,743 / 3.57E-05 * 3.68E-06 = $1,708,648

Based on a $975,000 cost of implementation for Braidwood, the net value for this SAMA is $733,648 ($1,708,648 - $975,000), which indicates this SAMA is potentially cost beneficial.

F.6.28 SAMA 29 SEAL THE INVERTER 111 PANEL AND INSTALL FIRE BARRIERS TO PROTECT NEARBY EQUIPMENT

The fire scenario initiated by a fire in inverter 111 is exacerbated by propagation of the fire such that it damages nearby equipment. Limiting the damage of the fire to the inverter itself would reduce the risk of the fire event.

Assumptions:

This SAMA will eliminate all of the risk associated with fire zone 5.6-1.

The ratio of internal events cost-risk to internal events CDF is equal to the ratio of fire cost-risk to fire CDF.

PRA Model Changes to Model SAMA:

The CDF associated with fire zone 5.6-1 was changed from 3.18E-06 to 0.0 to model the installation of the fire barriers.

Results of SAMA Quantification:

The averted cost-risk for this SAMA is the cost-risk associated with fire zone 5.6-1 because this SAMA is assumed to entirely eliminate it. Using the assumptions identified above, the result is as follows:

$16,575,743 / 3.57E-05 * 3.18E-06 = $1,476,495

Based on a $554,500 cost of implementation for Braidwood, the net value for this SAMA is $921,995 ($1,476,495 - $554,500), which indicates this SAMA is potentially cost beneficial.

F.6.29 SAMA 30 AUTOMATE SWAP TO RECIRCULATION MODE

Fully automating the swap to recirculation mode and removing the operator from the process can improve the reliability of the action.

Assumptions:

It is assumed that this SAMA will eliminate the contributions from the failure to swap to recirculation mode.

PRA Model Changes to Model SAMA:

The independent and dependent operator action events associated with recirculation initiation are set to 0.0 to represent this SAMA.

Model Change(s):

The following events were set to 0.0:

- 1SI-HPR----HSYOA: OPERATORS FAIL TO ESTABLISH HIGH PRESSURE RECIRC (SLOW EVENT)
- 1RX-JHEP19-HOADA and similar events for the following JHEP combinations: 36, 51, 55, and 71.

Results of SAMA Quantification:

Implementation of this SAMA yielded a moderate reduction in internal CDF and similar reductions in Dose-Risk and Offsite Economic Cost-Risk. The results are summarized in the following table:

	Internal CDF	Dose-Risk	OECR
Base Value	3.57E-05	113.76	$809,628
SAMA Value	3.53E-05	113.66	$808,566
Percent Change	1.1%	0.1%	0.1%

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

Release Category	$Freq._{BASE}$	$Freq._{SAMA}$	$Dose\text{-}Risk_{BASE}$	$Dose\text{-}Risk_{SAMA}$	$OECR_{BASE}$	$OECR_{SAMA}$
INTACT	1.34E-05	1.31E-05	3.32E-01	3.25E-01	$300	$293
SERF-TISGTR-HLF	8.12E-09	7.80E-09	3.01E-02	2.89E-02	$229	$220
SERF-SGTR-AFW-SC	1.48E-06	1.48E-06	5.70E+00	5.70E+00	$24,716	$24,716
LATE-BMMT-AFW	6.07E-07	6.05E-07	4.03E-02	4.02E-02	$31	$31
LATE-BMMT-NOAFW	9.95E-08	8.35E-08	1.90E-02	1.59E-02	$31	$26
LATE-CHR-AFW	1.37E-05	1.37E-05	2.14E+01	2.14E+01	$45,210	$45,210
LATE-CHR-NOAFW	7.51E-06	7.51E-06	6.59E+01	6.59E+01	$642,105	$642,105
LERF-ISLOCA	3.40E-07	3.40E-07	1.55E+01	1.55E+01	$54,400	$54,400
LERF-CI	3.63E-07	3.61E-07	1.18E+00	1.17E+00	$3,775	$3,754
LERF-CFE	3.14E-08	3.12E-08	2.92E-01	2.90E-01	$2,003	$1,991
LERF-SGTR-AFW	5.92E-08	5.92E-08	5.19E-01	5.19E-01	$4,422	$4,422
LERF-SGTR-NOAFW	9.64E-10	9.64E-10	2.98E-03	2.98E-03	$24	$24
LERF-ISGTR	2.57E-07	2.49E-07	2.80E+00	2.71E+00	$32,382	$31,374
Total	3.79E-05	3.75E-05	1.14E+02	1.14E+02	$809,628	$808,566

Applying the process described in Section F.4 yields an internal events cost-risk of $16,545,585. After accounting for “round up” of the base internal events cost-risk, this value is $16,545,842. The external events contributions are accounted for by multiplying this value by 2.8:

$$\text{Total Cost-Risk}_{\text{SAMA}} = \$16,545,842 * 2.8 = \$46,328,358$$

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

SAMA 30 Averted Cost-Risk

Unit	Base Case Cost-Risk	Revised Cost-Risk	Averted Cost-Risk
Braidwood Unit 1	$46,412,800	$46,328,358	$84,442

Based on a $1,225,000 cost of implementation for Braidwood, the net value for this SAMA is -$1,140,558 ($84,442 - $1,225,000), which indicates this SAMA is not cost beneficial.

F.6.30 SAMA 31 INSTALL FIRE BARRIERS AROUND MCCS 132X5 AND 134X

Fires that start in these MCCs are exacerbated by the propagation of the fire to nearby equipment. Installation of fire barriers to protect the equipment could mitigate the consequences of the fires.

Assumptions:

This SAMA will eliminate all of the risk associated with fire zone 11.6-0.

The ratio of internal events cost-risk to internal events CDF is equal to the ratio of fire cost-risk to fire CDF.

PRA Model Changes to Model SAMA:

The CDF associated with fire zone 11.6-0 was changed from 1.20E-06 to 0.0 to model the installation of the fire barriers.

Results of SAMA Quantification:

The averted cost-risk for this SAMA is the cost-risk associated with fire zone 11.6-0 because this SAMA is assumed to entirely eliminate it. Using the assumptions identified above, the result is as follows:

$$\$16,575,743 / 3.57E\text{-}05 * 1.20E\text{-}06 = \$557,168$$

Based on a $975,000 cost of implementation for Braidwood, the net value for this SAMA is -$417,832 ($557,168 - $975,000), which indicates this SAMA is not cost beneficial.

F.6.31 SAMA 32 INSTALL FIRE BARRIERS AROUND MCC 131X2

Fires that start in this MCC are exacerbated by the propagation of the fire to nearby equipment. Installation of fire barriers to protect the equipment could mitigate the consequences of the fires.

Assumptions:

This SAMA will eliminate all of the risk associated with fire zone 11.5a-1.

The ratio of internal events cost-risk to internal events CDF is equal to the ratio of fire cost-risk to fire CDF.

PRA Model Changes to Model SAMA:

The CDF associated with fire zone 11.5a-1 was changed from 1.05E-06 to 0.0 to model the installation of the fire barriers.

Results of SAMA Quantification:

The averted cost-risk for this SAMA is the cost-risk associated with fire zone 11.5a-1 because this SAMA is assumed to entirely eliminate it. Using the assumptions identified above, the result is as follows:

$16,575,743 / 3.57E-05 * 1.05E-06 = $487,522

Based on a $975,000 cost of implementation for Braidwood, the net value for this SAMA is -$487,478 ($487,522 - $975,000), which indicates this SAMA is not cost beneficial.

F.6.32 SAMA 33 UNIT 2 SAMA - INSTALL CABLE WRAP ON THE 141 TO 241 4KV CROSS-TIE CABLE IN THE DIVISION 11 ESF SWITCHGEAR ROOM

Fires initiating in the 143 bus cause damage to nearby equipment, including the cross-tie between buses 141 and 241. Failure of the cross-tie is assumed to result in the failure of both buses 141 and 241. A potential means of preventing loss of buses 141 and 241 is to install cable wrap on the 141-241 cross-tie cable.

Assumptions:

This SAMA will eliminate all of the risk associated with fire zone 5.2-1 (Unit 2).

The ratio of internal events cost-risk to internal events CDF is equal to the ratio of fire cost-risk to fire CDF.

PRA Model Changes to Model SAMA:

The CDF associated with fire zone 5.2-1 (Unit 2) was changed from 2.22E-06 to 0.0 to model the installation of the cable wrap.

Results of SAMA Quantification:

The averted cost-risk for this SAMA is the cost-risk associated with fire zone 5.2-1 (Unit 2) because this SAMA is assumed to entirely eliminate it. Using the assumptions identified above, the result is as follows:

$16,575,743 / 3.57E-05 * 2.22E-06 = $1,030,760

Based on a $975,000 cost of implementation for Braidwood, the net value for this SAMA is $55,760 ($1,030,760 - $975,000), which indicates this SAMA is potentially cost beneficial.

F.6.33 SAMA 34 UNIT 2 SAMA - INSTALL CABLE WRAP ON THE 141 TO 241 4KV CROSS-TIE CABLE IN THE AUX BUILDING ELEVATION 426' OF THE GENERAL AREA

Fires initiating in MCC 134X result in failure of bus 241 as a result of fire propagation and damage to nearby targets. A potential means of preventing loss of bus 241 is to install cable wrap on the 141-241 cross-tie cable.

Assumptions:

This SAMA will eliminate all of the risk associated with fire zone 11.6-0 (Unit 2).

The ratio of internal events cost-risk to internal events CDF is equal to the ratio of fire cost-risk to fire CDF.

PRA Model Changes to Model SAMA:

The CDF associated with fire zone 11.6-0 (Unit 2) was changed from 1.75E-06 to 0.0 to model the installation of the cable wrap.

Results of SAMA Quantification:

The averted cost-risk for this SAMA is the cost-risk associated with fire zone 11.6-0 (Unit 2) because this SAMA is assumed to entirely eliminate it. Using the assumptions identified above, the result is as follows:

$16,575,743 / 3.57E-05 * 1.75E-06 = $812,536

Based on a $975,000 cost of implementation for Braidwood, the net value for this SAMA is -$162,464 ($812,536 - $975,000), which indicates this SAMA is not cost beneficial.

F.6.34 SAMA 35 UNIT 2 SAMA - INSTALL CABLE WRAP TO PROTECT 2AF005A, B, C, AND D IN THE DIVISION 21 CONTAINMENT ELECTRICAL PENETRATIONS AREA

Fires initiating in MCC 231X2 and the pressurizer power supply transformer/panel result in failure of the 2AF005A-D valves. A potential means of preventing loss of division 1 AFW is to protect the cables related to the valves in this area.

Assumptions:

This SAMA will eliminate all of the risk associated with fire zone 11.5a-2 (Unit 2).

The ratio of internal events cost-risk to internal events CDF is equal to the ratio of fire cost-risk to fire CDF.

PRA Model Changes to Model SAMA:

The CDF associated with fire zone 11.5a-2 (Unit 2) was changed from 1.64E-06 to 0.0 to model the installation of the cable wrap.

Results of SAMA Quantification:

The averted cost-risk for this SAMA is the cost-risk associated with fire zone 11.5a-2 (Unit 2) because this SAMA is assumed to entirely eliminate it. Using the assumptions identified above, the result is as follows:

$16,575,743 / 3.57E-05 * 1.64E-06 = $761,463

Based on a $975,000 cost of implementation for Braidwood, the net value for this SAMA is -$213,537 ($761,463 - $975,000), which indicates this SAMA is not cost beneficial.

F.7 SENSITIVITY ANALYSIS

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

- Use a discount rate of 7 percent, instead of 3 percent used in the base case analysis.
- Use the 95th percentile PRA results in place of the point estimate PRA results.
- Selected MACCS2 input variables.
- Inclusion of the AFW Cross-tie modification as part of the base model

F.7.1 REAL DISCOUNT RATE

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

Based on the reduction in the MACR to $33,493,600 (a 28 percent reduction of the baseline MACR), one additional SAMA (SAMA 1) would be screened from the Phase 1 analysis. If a strict interpretation of the screening rules had applied in the baseline analysis (3 percent RDR), SAMA 1 would have been screened, but because the cost of implementation was so close to the MACR, it was retained for Phase 2 analysis.

The Phase 2 analysis was re-performed using the 7 percent RDR. As shown below, the determination of cost effectiveness changed for two of the Phase 2 SAMAs when the 7 percent RDR was used in lieu of 3 percent.

Summary of the Impact of the RDR Value on the Detailed SAMA Analyses

SAMA ID	Implementation Cost (per unit)	Averted Cost Risk (3 percent RDR)	Net Value (3 percent RDR)	Averted Cost Risk (7 percent RDR)	Net Value (7 percent RDR)	Change in Cost Effective-ness?
SAMA 1	46,430,968	$38,616,144	-$7,814,856	$27,786,802	- $18,644,198	No
SAMA 2	$5,751,110	$5,049,038	-$702,072	$3,740,831	-$2,010,279	No
SAMA 3	$1,130,300	$3,904,550	$2,774,250	$2,849,459	$1,719,159	No
SAMA 4	$12,230,000	$5,654,261	-$6,575,739	$4,177,062	-$8,052,938	No

Summary of the Impact of the RDR Value on the Detailed SAMA Analyses

SAMA ID	Implementation Cost (per unit)	Averted Cost Risk (3 percent RDR)	Net Value (3 percent RDR)	Averted Cost Risk (7 percent RDR)	Net Value (7 percent RDR)	Change in Cost Effective-ness?
SAMA 5	$657,200	$16,508,612	$15,851,412	$11,845,280	$11,188,080	No
SAMA 6	$100,000	$628,275	$528,275	$490,840	$390,840	No
SAMA 7	$100,000	$110,488	$10,488	$86,069	-$13,931	Yes
SAMA 8	$338,830	$731,867	$393,037	$535,416	$196,586	No
SAMA 9	$349,300	$1,560,502	$1,211,202	$1,140,863	$791,563	No
SAMA 10	$1,320,300	$5,144,524	$3,824,224	$3,718,165	$2,397,865	No
SAMA 11	$13,030,000	$38,012,495	$24,982,495	$27,396,034	$14,366,034	No
SAMA 13	$5,951,110	$38,172,716	$32,221,606	$27,501,356	$21,550,246	No
SAMA 14	$3,800,000	$150,710	-$3,649,290	$110,964	-$3,689,036	No
SAMA 15	$0	$1,220,685	$1,220,685	$880,569	$880,569	No
SAMA 16	$993,800	$3,272,982	$2,279,182	$2,348,489	$1,354,689	No
SAMA 17	$981,730	$53,046	-$928,684	$39,516	-$942,214	No
SAMA 18	$1,608,680	$308,798	-$1,299,882	$224,095	-$1,384,585	No
SAMA 19	$900,000	$2,751,185	$1,851,185	$1,971,180	$1,071,180	No
SAMA 20	$20,000,000	$45,654	-$19,954,346	$35,006	-$19,964,994	No
SAMA 21	$1,600,000	$695,797	-$904,203	$498,716	-$1,101,284	No
SAMA 22	$250,000	$158,799	-$91,201	$113,644	-$136,356	No
SAMA 23	$760,000	$108,982	-$651,018	$77,994	-$682,006	No
SAMA 24	$1,250,000	$116,575	-$1,133,425	$83,426	-$1,166,574	No
SAMA 25	$5,700,000	$32,667,169	$26,967,169	$23,377,830	$17,677,830	No
SAMA 26	$2,400,000	$37,958,155	$35,558,155	$27,355,588	$24,955,588	No
SAMA27	$975,000	$2,627,975	$1,652,975	$1,896,398	$921,398	No
SAMA28	$975,000	$1,708,648	$733,648	$1,232,994	$257,994	No
SAMA29	$554,500	$1,476,495	$921,995	$1,065,467	$510,967	No

Summary of the Impact of the RDR Value on the Detailed SAMA Analyses

SAMA ID	Implementation Cost (per unit)	Averted Cost Risk (3 percent RDR)	Net Value (3 percent RDR)	Averted Cost Risk (7 percent RDR)	Net Value (7 percent RDR)	Change in Cost Effective-ness?
SAMA30	$1,225,000	$84,442	-$1,140,558	$63,538	-$1,161,462	No
SAMA31	$975,000	$557,168	-$417,832	$402,063	-$572,937	No
SAMA32	$975,000	$487,522	-$487,478	$351,805	-$623,195	No
SAMA33	$975,000	$1,030,760	$55,760	$743,817	-$231,183	Yes
SAMA34	$975,000	$812,536	-$162,464	$586,342	-$388,658	No
SAMA35	$975,000	$761,463	-$213,537	$549,486	-$425,514	No

F.7.2 95TH PERCENTILE PRA RESULTS

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

A Level 1 internal events model uncertainty analysis was not performed for Braidwood model BB011b1. However, an uncertainty analysis was performed on Braidwood model BB011a in 2012. Since the 95th percentile assessment employs a ratio rather than individual values, a determination was made to use the BB011a uncertainty results. The basis for this decision is that the 95th to CDF point estimate ratio is not expected to vary significantly between the two models, and hence, should provide a representative value. The availability and use of Level 2 uncertainties is unique since most plants incorporate only Level 1 analyses in their SAMA reports. The reason Level 2 analyses are not typically used is due to the differing degree of development and uncertainties between the two models. Specifically, the Level 1 model tends to represent the plant in a more thorough and comprehensive manner as opposed to the Level 2 model. Furthermore, there are more release contributors beyond those captured by LERF. As such, for the purposes of the 95th percentile analysis, only Level 1 results are used in the uncertainty process. The results of the Level 1 calculation are provided below.

In performing the sensitivity analysis, only the base case was used in determining the appropriate value for the 95th percentile. For those SAMAs that required the addition of new basic events, no new uncertainty distributions were assigned since the design and implementation of each SAMA was arbitrary and was defined by the analysis assumptions. The results of this uncertainty analysis, therefore, show the expected statistical uncertainty of the CDF risk metrics under the assumption that each SAMA was designed and implemented as it was specified in this analysis. All calculations were performed using version 3.0 of the EPRI Uncert software package for the Braidwood Unit 1 model.

The results of the uncertainty calculation are shown in the table below. The term CDF_{pe} refers to the nominal BB011a CDF point estimate of 4.26E-05.

Summary of Uncertainty Distribution (from BB011a)

Mean	5%	50%	95%	Factor > CDF_{pe}
4.12E-05	1.36E-05	3.11E-05	9.77E-05	2.29

The above table reveals a factor that is 2.29 greater than the respective point estimate CDF, which is in agreement with industry experience. Therefore, for this analysis, the 95th percentile multiplier derived from the base case is used to examine the change in the cost benefit for each SAMA.

F.7.2.1 PHASE 1 IMPACT

For Phase 1 screening, use of the 95th percentile PRA results will increase the MACR and may prevent the screening of some of the higher cost modifications. However, the impact on the overall SAMA results due to the retention of the higher cost SAMAs for Phase 2 analysis is typically small. This is due to the fact that the benefit obtained from the implementation of those SAMAs must be extremely large in order to be cost beneficial.

The impact of uncertainty in the PRA results on the Phase 1 SAMA analysis has been examined. The MACR is the primary Phase 1 criterion affected by PRA uncertainty. Thus, this portion of the sensitivity is focused on recalculating the MACR using the 95th percentile PRA results and re-performing the Phase 1 screening process. As discussed above, the 95th PRA results are a factor of 2.29 greater than the point estimate CDF.

In order to simulate the use of the 95th percentile PRA results on the cost benefit calculations, the same scaling factor calculated for the Level 1 results was assumed to apply to the Level 3 results. Because the MACR calculations scale linearly with the CDF, dose-risk, and off-site economic cost-risk, the 95th percentile MACR can be calculated by multiplying the base case MACR by 2.29. This results in a 95th percentile MACR of $106,285,312.

The initial SAMA list has been re-examined using the revised MACR to identify SAMAs that would have been retained for the Phase 2 analysis. Those SAMAs that were previously screened due to costs of implementation that exceeded $46.4 million are now retained if the costs of implementation are less than $106,285,312. For Braidwood, only SAMA 12 was screened in the Phase 1 analysis based on excessive implementation cost. Because the SAMA 12 implementation cost is less than the 95th percentile MACR, it has been retained for Phase 2 analysis.

Based on a detailed quantification of SAMA 12, a new averted cost risk and net value at the 95th percentile was generated. As shown below, the net value remained negative for SAMA 12. In fact, the net value was significantly negative, providing further justification for screening it from consideration.

F.7.2.1.1 SAMA 12: Modify Practices for SAT Maintenance or Enhance Procedures

For on-line SAT maintenance, a single SAT can provide power to the loads normally supplied by both SATs on a given unit. However, in order to align this configuration, there is a transition period during which both SATs are unable to provide power to any bus. For loss of SX events, this condition is critical because it eliminates the ability to provide power to the Feedwater system for heat removal, which is the only heat removal mechanism available without SX (due to system dependencies). Precluding on-line SAT maintenance is a potential means of reducing this on-line risk. Alternatively, existing Braidwood procedures could be modified to serve as contingency procedures for these maintenance evolutions. Braidwood has procedures to provide power to the buses required to power the Startup Feedwater pump, but they are not clearly linked to address the SAT maintenance scenario. Providing clear contingency procedures to perform the required power alignment could help reduce the risk of these scenarios.

Assumptions:

Eliminating on-line maintenance of the SATs would completely remove the risk of planned evolutions in which both SATs are unavailable while implementation of contingency procedures would only reduce the risk. For this assessment, however, it is assumed that both options completely eliminate the risk of this configuration.

No assessment is made of any increase in risk associated with performing the maintenance work during outage conditions.

PRA Model Changes to Model SAMA:

The database was changed to set the probability of the dual SAT maintenance configuration to zero. In addition, the single SAT maintenance terms were set to zero given that elimination of the dual SAT out of service configuration implies that no on-line SAT maintenance is performed.

Model Change(s):

The following modeling changes were made:

- 1AP-BOTHSAT-TRMM (BOTH U1 SAT OOS FOR TM - 141 PWR VIA 241; 142 PWR VIA 242; 156 - 159 ON UAT): Set to 0.0
- 2AP-BOTHSAT-TRMM (BOTH U2 SAT OOS FOR TM - 241 PWR VIA 141; 242 PWR VIA 142; 256 - 259 ON UAT): Set to 0.0.
- 1AP-142-1---TRMM (SAT 142-1 IS UNAVAILABLE DUE TO MAINTENANCE (141 PWR SUPPLIED FROM SAT 142-2): Set to 0.0.
- 1AP-142-2---TRMM (SAT 142-2 IS UNAVAILABLE DUE TO MAINTENANCE): Set to 0.0.
- 2AP-242-1---TRMM (SAT 242-1 IS UNAVAILABLE DUE TO MAINTENANCE): Set to 0.0.
- 2AP-242-2---TRMM (SAT 242-2 IS UNAVAILABLE DUE TO MAINTENANCE): Set to 0.0.

Results of SAMA Quantification:

Implementation of this SAMA yielded a moderate reduction in internal CDF and similar reductions in Dose-Risk and Offsite Economic Cost-Risk. The results are summarized in the following table:

	Internal CDF	**Dose-Risk**	**OECR**
Base Value	3.57E-05	113.76	$809,628
SAMA Value	3.42E-05	100.46	$680,770
Percent Change	4.2%	11.7%	15.9%

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

Release Category	$Freq._{BASE}$	$Freq._{SAMA}$	$Dose\text{-}Risk_{BASE}$	$Dose\text{-}Risk_{SAMA}$	$OECR_{BASE}$	$OECR_{SAMA}$
INTACT	1.34E-05	1.34E-05	3.32E-01	3.32E-01	$300	$300
SERF-TISGTR-HLF	8.12E-09	8.12E-09	3.01E-02	3.01E-02	$229	$229
SERF-SGTR-AFW-SC	1.48E-06	1.48E-06	5.70E+00	5.70E+00	$24,716	$24,716
LATE-BMMT-AFW	6.07E-07	6.07E-07	4.03E-02	4.03E-02	$31	$31
LATE-BMMT-NOAFW	9.95E-08	9.90E-08	1.90E-02	1.89E-02	$31	$31
LATE-CHR-AFW	1.37E-05	1.36E-05	2.14E+01	2.12E+01	$45,210	$44,880
LATE-CHR-NOAFW	7.51E-06	6.07E-06	6.59E+01	5.33E+01	$642,105	$518,985
LERF-ISLOCA	3.40E-07	3.40E-07	1.55E+01	1.55E+01	$54,400	$54,400
LERF-CI	3.63E-07	3.49E-07	1.18E+00	1.13E+00	$3,775	$3,630
LERF-CFE	3.14E-08	3.00E-08	2.92E-01	2.79E-01	$2,003	$1,914
LERF-SGTR-AFW	5.92E-08	5.91E-08	5.19E-01	5.18E-01	$4,422	$4,415
LERF-SGTR-NOAFW	9.64E-10	9.64E-10	2.98E-03	2.98E-03	$24	$24
LERF-ISGTR	2.57E-07	2.16E-07	2.80E+00	2.35E+00	$32,382	$27,216
Total	3.79E-05	3.63E-05	1.14E+02	1.00E+02	$809,628	$680,770

Applying the process described in Section F.4 yields an internal events cost-risk of $14,196,473. After accounting for "round up" of the base internal events cost-risk, this value is $14,196,730. The external events contributions are accounted for by multiplying this value by 2.8:

$$\text{Total Cost-Risk}_{SAMA} = \$14{,}196{,}730 * 2.8 = \$39{,}750{,}844$$

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

SAMA 12 Averted Cost-Risk

Unit	Base Case Cost-Risk	Revised Cost-Risk	Averted Cost-Risk
Braidwood Unit 1	$46,412,800	$39,750,844	$6,661,956

Based on a $70,000,000 cost of implementation for Braidwood, the net value for this SAMA in the base case is -$63,338,044 ($6,661,956 - $70,000,000). When the 95th percentile PRA results are used, the averted cost-risk is increased by a factor of 2.29 to $15,255,879, which still yields a negative net value ($15,255,879 - $70,000,000 = -$54,744,121). This SAMA is not cost beneficial.

F.7.2.2 PHASE 2 IMPACT

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

The Phase 2 SAMA list was re-examined by multiplying the nominal averted cost risk by the ratio of the 95th percentile CDF to the point estimate CDF value (see Section 7.2) to identify SAMAs that would be re-characterized as potentially cost beneficial, i.e., positive net value. Those SAMAs that were previously determined to be not cost beneficial due to implementation costs exceeding their associated nominal averted cost risk may be potentially cost beneficial at the revised 95th percentile averted cost risk. In this case, nine additional Phase 2 SAMAs become potentially cost beneficial (SAMAs 1, 2, 4, 21, 22, 31, 32, 34, and 35).

F.7.2.3 95TH PERCENTILE SUMMARY

The following table provides a summary of the impact of using the 95th percentile PRA results on the detailed cost-benefit calculations that have been performed.

Summary of the Impact of Using the 95th Percentile PRA Results

SAMA ID	Implementation Cost (per unit)	Averted Cost Risk (Base)	Net Value (Base)	Averted Cost Risk (95th Percentile)	Net Value (95th Percentile)	Change in Cost Effective-ness?
SAMA1	$46,430,968	$38,616,144	-$7,814,856	$88,430,970	$41,999,970	Yes
SAMA2	$5,751,110	$5,049,038	-$702,072	$11,562,297	$5,811,187	Yes
SAMA3	$1,130,300	$3,904,550	$2,774,250	$8,941,420	$7,811,120	No
SAMA4	$12,230,000	$5,654,261	-$6,575,739	$12,948,258	$718,258	Yes
SAMA5	$657,200	$16,508,612	$15,851,412	$37,804,721	$37,147,521	No
SAMA6	$100,000	$628,275	$528,275	$1,438,750	$1,338,750	No
SAMA7	$100,000	$110,488	$10,488	$253,018	$153,018	No
SAMA8	$338,830	$731,867	$393,037	$1,675,975	$1,337,145	No
SAMA9	$349,300	$1,560,502	$1,211,202	$3,573,550	$3,224,250	No
SAMA10	$1,320,300	$5,144,524	$3,824,224	$11,780,960	$10,460,660	No
SAMA11	$13,030,000	$38,012,495	$24,982,495	$87,048,614	$74,018,614	No
SAMA12	$70,000,000	$6,661,956	-$63,338,044	$15,255,879	-$54,744,121	No
SAMA13	$5,951,110	$38,172,716	$32,221,606	$87,415,520	$81,464,410	No
SAMA14	$3,800,000	$150,710	-$3,649,290	$345,126	-$3,454,874	No
SAMA15	$0	$1,220,685	$1,220,685	$2,795,369	$2,795,369	No
SAMA16	$993,800	$3,272,982	$2,279,182	$7,495,129	$6,501,329	No
SAMA17	$981,730	$53,046	-$928,684	$121,475	-$860,255	No
SAMA18	$1,608,680	$308,798	-$1,299,882	$707,147	-$901,533	No
SAMA19	$900,000	$2,751,185	$1,851,185	$6,300,214	$5,400,214	No
SAMA20	$20,000,000	$45,654	-$19,954,346	$104,548	-$19,895,452	No
SAMA21	$1,600,000	$695,797	-$904,203	$1,593,375	-$6,625	No
SAMA22	$250,000	$158,799	-$91,201	$363,650	$113,650	Yes
SAMA23	$760,000	$108,982	-$651,018	$249,569	-$510,431	No
SAMA24	$1,250,000	$116,575	-$1,133,425	$266,957	-$983,043	No
SAMA25	$5,700,000	$32,667,169	$26,967,169	$74,807,817	$69,107,817	No
SAMA26	$2,400,000	$37,958,155	$35,558,155	$86,924,175	$84,524,175	No

Summary of the Impact of Using the 95th Percentile PRA Results

SAMA ID	Implementation Cost (per unit)	Averted Cost Risk (Base)	Net Value (Base)	Averted Cost Risk (95th Percentile)	Net Value (95th Percentile)	Change in Cost Effective-ness?
SAMA27	$975,000	$2,627,975	$1,652,975	$6,018,063	$5,043,063	No
SAMA28	$975,000	$1,708,648	$733,648	$3,912,804	$2,937,804	No
SAMA29	$554,500	$1,476,495	$921,995	$3,381,174	$2,826,674	No
SAMA30	$1,225,000	$84,442	-$1,140,558	$193,372	-$1,031,628	No
SAMA31	$975,000	$557,168	-$417,832	$1,275,915	$300,915	Yes
SAMA32	$975,000	$487,522	-$487,478	$1,116,425	$141,425	Yes
SAMA33	$975,000	$1,030,760	$55,760	$2,360,440	$1,385,440	No
SAMA34	$975,000	$812,536	-$162,464	$1,860,707	$885,707	Yes
SAMA35	$975,000	$761,463	-$213,537	$1,743,750	$768,750	Yes

When the 95th percentile PRA results were applied to the Phase 1 analysis, the increase in the MACR resulted in the retention of only one SAMA that was screened in the baseline Phase 1 analysis (SAMA 12). The Phase 2 analysis performed for SAMA 12 using the 95th percentile PRA results confirmed that SAMA 12 is not cost beneficial.

When the 95th percentile PRA results were applied to the Phase 2 analysis, nine SAMAs (1, 2, 4, 21, 22, 31, 32, 34, and 35) that were previously classified as not cost effective were determined to be potentially cost effective. The use of the 95th percentile PRA results is not considered to provide the best assessment of the cost effectiveness of a SAMA; however, these additional SAMAs should be considered for implementation to address the uncertainties inherent in the SAMA analysis.

F.7.3 MACCS2 INPUT VARIATIONS

The MACCS2 model was developed using the best information available for the Braidwood site; however, reasonable changes to modeling assumptions can lead to variations in the Level 3 results. In order to determine how certain assumptions could impact the SAMA results, a sensitivity analysis was performed on parameters that have previously been shown to impact the Level 3 results. These parameters include:

- Meteorological data

- Evacuation timing and speed
- Release height and heat
- Deposition velocity
- Reactor power level
- Population estimates
- Population resettlement planning
- Generic economic inputs
- Economic rate of return

The risk metrics produced by MACCS2 that are evaluated in the sensitivity analyses are the 50 mile population dose risk and the 50 mile offsite economic cost risk. The subsections below discuss the changes in these results for each of the sensitivity parameters noted above. The final subsection, F.7.3.10, correlates the worst case changes identified in the sensitivity runs to a change in the site's averted cost-risk and discusses the implications of the sensitivity analysis on the SAMA analysis.

Sensitivity of Braidwood Baseline Risk to Parameter Changes

Parameter	Description	Pop. Dose Risk Δ Base (%)	Cost Risk Δ Base (%)
Meteorology	Year 2008 Meteorology	-2%	-2%
	Year 2009 Meteorology	-3%	0%
Evacuation Time	Evacuation delay time increased from 115 minutes to 230 minutes (factor of 2)	+0.7%	0%
Evacuation Speed	Average evacuation speed decreased 67% from 4.2 m/sec to 1.4 m/sec.	+5%	0%
Release Height	Release height set to ground level (in lieu of mid-height of containment, 30.3 m).	-2%	-4%
	Release height set to top of containment , 60.7m (in lieu of mid-height of containment, 30.3 m).	+2%	+2%
Release Heat	No buoyant plume assumed (0 watts for each plume segment).	-3%	-8%
Deposition Velocity	Dry deposition velocity decreased from 0.01 m/sec to 0.005 m/sec (factor of 2)	-10%	-21%
Reactor Power	Reactor power decreased from 3645 MWt to 3586.6 MWt, reflective of no MUR uprate	-1%	-1%

Sensitivity of Braidwood Baseline Risk to Parameter Changes

Parameter	Description	Pop. Dose Risk Δ Base (%)	Cost Risk Δ Base (%)
Population	Year 2047 population uniformly increased 30%	+30%	+29%
Resettlement Planning	No "Intermediate Phase" resettlement planning (in lieu of 6 months)	+17%	-40%
	1 year "Intermediate Phase" resettlement planning (in lieu of 6 months)	-13%	+41%
Economic Inputs	Generic economic inputs increased (factor of 2)	-4%	+52%
Rate of Return	3% expected rate of return (in lieu of 7%)	+1%	-9%
	12% expected rate of return (in lieu of 7%)	-1%	+11%

F.7.3.1 METEOROLOGICAL SENSITIVITIES

In addition to the year 2010 base case meteorological data, years 2008 and 2009 were also analyzed. Analysis of year 2008 and 2009 data sets yielded population dose-risks and cost risks that were 0 to 3% less than 2010 results. As no particular criteria have been defined by the industry related to determining which meteorological data set should be used as a base case for a site, the year 2010 data is chosen for Braidwood given that it represents site meteorological conditions and results in the highest dose risk and cost risk of the three data sets.

F.7.3.2 EVACUATION SENSITIVITIES

The sensitivity of two evacuation parameters was assessed. The delay time to evacuation (increased from 115 minutes to 230 minutes) was found to have a very minor impact (approximately 0.7% increase) on population dose risk. The evacuation speed sensitivity which decreased the average radial evacuation speed by a factor of three (from 4.2 m/sec to 1.4 m/sec) demonstrates a small impact on population dose. The population dose risk increased approximately 5% using the slower evacuation speed. An increase in population dose is the generally expected result for a delayed evacuation or a slower evacuation speed since evacuees would be expected to be exposed to releases for a longer period of time. It is noted that while evacuation assumptions do impact the population dose-risk estimates, they do not impact MACCS2 offsite economic cost-risk estimates because MACCS2 calculated cost-risks are based on land contamination levels which remain unaffected by evacuation assumptions and the number of people evacuating.

F.7.3.3 RELEASE HEIGHT & HEAT SENSITIVITIES

The release height sensitivity cases quantify the impact of the assumption related to the height of the release of the plumes. The baseline case assumes that the releases occur at approximately half the height of the containment building (30.3 m). Releases from higher heights tend to disperse material over a wider geographical region, generally impacting more people and creating larger long term dose and cleanup costs. A ground level release height (0 m) shows a decrease in dose risk and cost risk of 2% and 4%, respectively. A release from the top of containment (60.3 m) shows an increase in dose risk and cost risk of 2%. The impacts of release height assumptions are small.

The release heat sensitivity case evaluates the impact of assumptions of thermal plume effects. The base case assumed a heat content of 10 MW per plume segment, except for the intact containment release category where zero plume heat was assumed. The 10 MW per plume segment value is generally bounding for the values used in the NUREG-1150 (NRC 1990a) study as documented in NUREG/CR-4551 (NRC 1990b). Modeling plume heat increases the buoyancy effect of the released plumes and generally has similar impacts as modeling a higher release height. The sensitivity case assumed no thermal plume heat in the releases (i.e., no buoyant plumes). The impacts of assuming no plume heat are a dose risk and cost risk decrease of 3% and 8%, respectively.

F.7.3.4 DEPOSITION VELOCITY

The dry deposition velocity sensitivity case evaluates the impact of the fission product particle size as reflected in the deposition velocity parameter. The base case assumes a deposition velocity of 0.01 m/sec, consistent with the NRC recommendation documented in MACCS2 Sample Problem A (NRC 1998). The sensitivity case uses a deposition velocity of 0.005 m/sec, reflective of a smaller particle size. Assuming a lower deposition velocity results in a decrease in the dose risk and cost risk of 10% and 21%, respectively. This decrease is attributed to smaller particles traveling further and exiting the 50 mile analysis region.

F.7.3.5 REACTOR POWER

The reactor power sensitivity case evaluates the impact of not including the postulated measurement uncertainty recapture (MUR) power uprate. For this sensitivity case, the reactor power was decreased from 3645 MWt (assumes MUR implemented) to 3586.6 MWt (current licensed power level). Assuming the MUR power uprate is not implemented results in a very small decrease of dose risk and cost risk of 1%.

F.7.3.6 POPULATION SENSITIVITY

A population sensitivity case assesses the impact of population assumptions. The base case year 2047 population is uniformly increased by 30% in all grid elements of the 50-mile radius. This change has a significant impact on the dose risk and cost risk, increasing dose risk and cost risk by 30% and 29%, respectively. This sensitivity case demonstrates a significant dependence upon population estimates. This dependence is expected given that population dose and offsite economic costs are primarily driven by the regional population.

F.7.3.7 RESETTLEMENT PLANNING SENSITIVITIES

The MACCS2 consequence modeling incorporates an “intermediate phase” which depicts the time period following the release and immediate evacuation actions (termed the “early phase”) and extends to the time when recovery efforts such as decontamination and resettlement of people are begun (termed the “long term phase”). The intermediate phase thus models the time period when decontamination and resettlement plans are being developed. MACCS2 allows the habitation of land during the intermediate phase unless projected dose criteria is exceeded, in which case individuals are relocated. MACCS2 allows an intermediate phase ranging from no intermediate phase to a maximum of one year. The intermediate phase sensitivities show significant impacts and are therefore discussed further:

- The no intermediate phase resettlement planning case is developed based on the NUREG-1150 (NRC 1990a) modeling approach. The 40% reduction in cost risk seen in the sensitivity results, however, is judged too optimistic in that the land decontamination efforts are modeled as starting one week after the accident (i.e., directly after the early phase ends) such that a significant portion of population relocation costs are omitted. For instance, the costs associated with temporary housing of interdicted individuals while decontamination strategies are developed and decontamination teams are contracted are not accounted for without an intermediate phase. It is believed that the NUREG-1150 studies omitted the intermediate phase because the intermediate phase coding was not validated at that time (NRC 1998). A competing factor is that the population dose increases (17% increase over the base case) because people are allowed to re-occupy the decontaminated land sooner.
- The 1 year intermediate phase resettlement planning case is developed based on the maximum length of time allowed by MACCS2 for the intermediate phase. A long intermediate phase can be unrealistic in that re-occupation of contaminated land is not performed during this phase even if contamination levels decrease (by natural radioactive decay and weathering) to levels which would allow it (i.e., resettlement is evaluated as part of the long term phase, not the intermediate phase). Therefore population relocation costs may be over estimated using a long (i.e., one year) intermediate phase. An intermediate phase of one year shows a 41% increase in cost risk estimates compared with the base

case selection of 6 months. The population dose decreased by 13% with a longer intermediate phase due to later resettlement on decontaminated land.

The six month intermediate phase (base case) is judged to be a best estimate approach in that it provides reasonable time for both decontamination and resettlement planning to be performed. The sensitivity cases demonstrate that the six month value used in the base case provides mid-range results for the modeling choices available.

F.7.3.8 GENERIC ECONOMIC INPUTS SENSITIVITY

MACCS2 requires certain site specific economic data (fraction of land devoted to farming, annual farm sales, fraction of farm sales resulting from dairy production, and property value of farm and non-farm land) for each of the 160 spatial elements. The site specific base case values are calculated based on regional economic data.

In addition to these site specific values, generic economic data are utilized by MACCS2 to address costs associated with per diem living expenses (applied to owners of interdicted properties and relocated populations), relocation costs (for owners of interdicted properties), and decontamination costs. For the Braidwood base case, these generic costs are based on values used in the NUREG-1150 study (NRC 1990a) as documented in the NUREG/CR-4551 (NRC 1990b) updated to July 2012 using the consumer price index.

This sensitivity case is performed to determine the variability in population dose risk and cost risk based on changes to these generic based values. The sensitivity case increases key generic based economic parameters as identified in Table F.7-1. In general, the inputs were arbitrarily increased by factor of 2.0. The increase in these economic parameters resulted in an increase in cost risk of 52% and a decrease in dose risk of about 4%. A significant increase in cost risk is expected since population relocation and decontamination costs are major contributors to total cost as calculated by MACCS2.

F.7.3.9 RATE OF RETURN SENSITIVITIES

One of the economic cost components included in the MACCS2 calculated cost result is the financial loss associated with property and associated improvements (e.g., buildings) not achieving their expected annual rate of return during interdiction periods. A piece of land that is interdicted (i.e., not occupied) for a period of years will not achieve the historical rate of return or the rate of return achieved by other non-impacted properties during the interdiction period. This lack of expected return is an economic loss for the owner / society. The base case assumes a

7% expected rate of return, consistent with NRC guidance (NRC 2004a). A sensitivity case using a 3% expected rate of return shows a decrease in the expected cost risk of approximately 9%. This decrease in cost risk associated with the lower rate or return is expected since there is a lower expectation associated with the land's return on investment. A sensitivity case using a 12% expected rate of return, the value used in NUREG-1150 MACCS2 analyses (NRC 1990b), shows an increase cost risk of approximately 11%. For both sensitivity cases the dose risk changes are minor (1%).

F.7.3.10 IMPACT ON SAMA ANALYSIS

Several different Level 3 input parameters are examined as part of the Braidwood MACCS2 sensitivity analysis. The primary reason for performing these sensitivity runs is to identify any reasonable changes that could be made to the Level 3 input parameters that would impact the conclusions of the SAMA analysis. While the table in Section F.7.3 summarizes the changes to the dose-risk and OECR estimates for each sensitivity case, it is prudent to consider if any of these changes would result in the retention of the SAMAs that were screened using the baseline results.

Of all the MACCS2 sensitivity cases, the largest dose-risk increase, 30%, occurred in the Population (Year 2047 population uniformly increased 30%) case. The largest OECR increase, 52%, occurred in the Generic Economic Input sensitivity case. While these changes are not insignificant, they are relatively small compared to the 95th percentile PRA results sensitivity in Section F.7.2, which increases the averted cost-risk values for the SAMAs by over 200 percent. Therefore, the 95th percentile PRA results sensitivity is considered to bound this case and no SAMAs would be retained based on this sensitivity that were not already identified in Section F.7.2.

F.7.4 INCLUSION OF THE AFW CROSS-TIE IN THE BASE MODEL

While the AFW Cross-tie modification is in the final stages of implementation for Braidwood, it was not officially implemented at the time the SAMA analysis was performed. Accordingly, the PRA model used for this analysis does not credit the AFW cross-tie. However, because the final implementation is imminent, a sensitivity analysis was performed to identify how the cross-tie capability would impact the SAMA analysis. In order to do this, the SAMA 15 (AFW Cross-tie) model was used as the new "base" model and the Phase 1 and 2 screening analyses were re-performed relative to that model.

Use of the SAMA 15 model as the base case resulted in a decrease in the MACR from $64,713,600 to $63,028,969, which is based on the PRA results documented in Section F.6.14 and the rounding up of the internal events cost-risk in the same manner as the base case. This slight reduction did not result in the screening of any additional SAMAs in the Phase 1 analysis.

The impact on the Phase 2 analysis was determined by performing the calculation/model changes identified for each SAMA in conjunction with the changes identified for SAMA 15. The following table provides a comparison of the Phase 2 results for the nominal plant configuration to the configuration in which the AFW Cross-tie has been implemented. As documented in the "Change in Cost Effectiveness?" column, implementation of the AFW cross-tie is would not alter the conclusions of the cost-benefit analysis.

Impact of Assuming Implementation of AFW Cross-tie for the SAMA Base Case

SAMA ID	Implementation Cost (per unit)	Averted Cost Risk (Base)	Net Value (Base)	Averted Cost Risk (SAMA 15 as Base Case)	Net Value (SAMA 15 as Base Case)	Change in Cost Effective-ness?
SAMA1	$46,430,968	$38,616,144	-$7,814,856	$37,633,576	-$8,797,424	No
SAMA2	$5,751,110	$5,049,038	-$702,072	$5,048,812	-$702,298	No
SAMA3	$1,130,300	$3,904,550	$2,774,250	$2,984,568	$1,854,268	No
SAMA4	$12,230,000	$5,654,261	-$6,575,739	$5,702,732	-$6,527,268	No
SAMA5	$657,200	$16,508,612	$15,851,412	$16,457,490	$15,800,290	No
SAMA6	$100,000	$628,275	$528,275	$614,298	$514,298	No
SAMA7	$100,000	$110,488	$10,488	$110,440	$10,440	No
SAMA8	$338,830	$731,867	$393,037	$730,425	$391,595	No
SAMA9	$349,300	$1,560,502	$1,211,202	$1,603,896	$1,254,596	No
SAMA10	$1,320,300	$5,144,524	$3,824,224	$5,134,707	$3,814,407	No
SAMA11	$13,030,000	$38,012,495	$24,982,495	$36,800,165	$23,770,165	No
SAMA12	$70,000,000	$6,661,956	-$63,338,044	$6,654,276	-$63,345,724	No
SAMA13	$5,951,110	$38,172,716	$32,221,606	$37,184,770	$31,233,660	No
SAMA14	$3,800,000	$150,710	-$3,649,290	$115,654	-$3,684,346	No
SAMA16	$993,800	$3,272,982	$2,279,182	$3,271,540	$2,277,740	No
SAMA17	$981,730	$53,046	-$928,684	$45,340	-$936,390	No

Impact of Assuming Implementation of AFW Cross-tie for the SAMA Base Case

SAMA ID	Implementation Cost (per unit)	Averted Cost Risk (Base)	Net Value (Base)	Averted Cost Risk (SAMA 15 as Base Case)	Net Value (SAMA 15 as Base Case)	Change in Cost Effective-ness?
SAMA18	$1,608,680	$308,798	-$1,299,882	$300,779	-$1,307,901	No
SAMA19	$900,000	$2,751,185	$1,851,185	$2,743,516	$1,843,516	No
SAMA20	$20,000,000	$45,654	-$19,954,346	$23,685	-$19,976,315	No
SAMA21	$1,600,000	$695,797	-$904,203	$688,134	-$911,866	No
SAMA22	$250,000	$158,799	-$91,201	$158,799	-$91,201	No
SAMA23	$760,000	$108,982	-$651,018	$107,593	-$652,407	No
SAMA24	$1,250,000	$116,575	-$1,133,425	$114,080	-$1,135,920	No
SAMA25	$5,700,000	$32,667,169	$26,967,169	$31,768,797	$26,068,797	No
SAMA26	$2,400,000	$37,958,155	$35,558,155	$36,741,872	$34,341,872	No
SAMA27	$975,000	$2,627,975	$1,652,975	$2,625,034	$1,650,034	No
SAMA28	$975,000	$1,708,648	$733,648	$1,706,736	$731,736	No
SAMA29	$554,500	$1,476,495	$921,995	$1,474,842	$920,342	No
SAMA30	$1,225,000	$84,442	-$1,140,558	$49,675	-$1,175,325	No
SAMA31	$975,000	$557,168	-$417,832	$556,544	-$418,456	No
SAMA32	$975,000	$487,522	-$487,478	$486,976	-$488,024	No
SAMA33	$975,000	$1,030,760	$55,760	$1,029,607	$54,607	No
SAMA34	$975,000	$812,536	-$162,464	$811,627	-$163,373	No
SAMA35	$975,000	$761,463	-$213,537	$760,611	-$214,389	No

F.8 CONCLUSIONS

The benefits of revising the operational strategies in place at Braidwood and/or implementing hardware modifications can be evaluated without the insight from a risk-based analysis. However, use of the PRA in conjunction with cost-benefit analysis methodologies provides an enhanced understanding of the effects of the proposed changes relative to the cost of implementation and projected impact on a larger future population. The results of this study indicate that many potential improvements were identified that warrant further review for potential implementation at Braidwood.

In summary, SAMAs 3, 5, 6, 7, 8, 9, 10, 11, 13, 15, 16, 19, 25, 26, 27, 28, 29, and 33 were found to be potentially cost beneficial in the baseline analysis.

When the 95th percentile PRA results are considered, SAMAs 1, 2, 4, 22, 31, 32, 34 and 35 are also potentially cost beneficial.

F.8.1 OPTIMAL SAMA SET

While many SAMAs are potentially cost beneficial for Braidwood when considered independently, it should be noted that many SAMAs address similar areas of risk. Implementation of one SAMA may result in a change in the potential benefits of the remaining SAMAs such that they are no longer cost beneficial. Review of the potentially cost beneficial SAMAs can help identify an “optimal” set of SAMAs for implementation, that is, a reduced set of SAMAs that will address the largest risk contributors for the site. For example, the industry initiative to address Fukushima insights led to the development of a mitigation strategy with capabilities similar to SAMA 11 (DMS), which may be fully implemented or implemented in part by Braidwood for reasons outside of the SAMA analysis, but would mitigate many of the largest contributors to site risk. In addition, the AFW Cross-tie is in the final stages of implementation and should be considered as complete for any future considerations. Beginning with these plant enhancements, the remaining set of SAMAs can be reviewed to identify those that would mitigate the contributors not addressed by SAMAs 11 and 15. It is recognized that there are different combinations of SAMAs that could achieve similar results, but this is a demonstration of a potential approach to interpreting the results of the cost benefit analysis.

Assuming that the AFW Cross-tie and the DMS have been implemented, the SAMAs that were identified as potentially cost beneficial in the 95th percentile sensitivity analysis were assessed to determine if they would remain potentially cost beneficial. The following table summarizes the results of this review.

Review of Impact of the DMS and AFW Cross-Tie on Cost Benefit Analysis

SAMA Number	SAMA Title	Discussion
1	Diesel Driven SX Pump	After implementation of the DMS alone, the unit MACR is reduced to $8.4 million. Even when the 95th percentile PRA results are considered, the value would be $19.2 million, which is less than the $48.7 million implementation cost of SAMA 1. This SAMA would no longer be cost beneficial.
2	Replace the Positive Displacement Pump with a Self-Cooled, Auto Start Pump	This SAMA is intended to prevent RCP seal LOCAs, but the DMS virtually eliminates the RCP seal LOCA contribution through the installation of “no-leak” seals. SAMA 2 would no longer be cost beneficial.
3	Auto Start of Standby SX Pump	Automating the start of the standby SX pump is primarily used to prevent RCP seal LOCAs. The DMS virtually eliminates the RCP seal LOCA contribution through the installation of “no-leak” seals. SAMA 3 would no longer be cost beneficial.
4	Install "No Leak" RCP Seals	This SAMA is part of the DMS and is no longer applicable as an independent SAMA.
5	Modify the Startup Feedwater Pump to Start Using the AMSAC SG Low-Low-Low Level signal to Mitigate AFW Failure	This SAMA addresses human errors associated with initiation of secondary side heat removal, which would not be impacted by the DMS. SAMA 5 would remain a viable candidate for potential implementation.
6	Enhance Plant Procedures to Explicitly Confirm Adequate _SX007 Throttling	This SAMA helps reduce human errors made in scenarios where the _SX007 valve must be throttled for heat removal, which are dominated by small and medium LOCA scenarios that the DMS would not mitigate. SAMA 6 would remain a viable candidate for potential implementation.
7	Establish Flow to the RH HX on RH Pump Start	This SAMA helps reduce human errors after successful initiation of heat removal, which are dominated by small LOCA scenarios that the DMS would not mitigate. SAMA 7 would remain a viable candidate for potential implementation.

Review of Impact of the DMS and AFW Cross-Tie on Cost Benefit Analysis

SAMA Number	SAMA Title	Discussion
8	Install Kill Switches for the Fire Protection Pumps in the MCR	This SAMA primarily protects the SX pumps, which in turn helps prevent RCP seal LOCAs. The DMS virtually eliminates the RCP seal LOCA contribution through the installation of "no-leak" seals. SAMA 8 would no longer be cost beneficial.
9	Install Flow Restrictors in Fire Protection Pipes	This SAMA primarily protects the SX pumps, which in turn helps prevent RCP seal LOCAs. The DMS virtually eliminates the RCP seal LOCA contribution through the installation of "no-leak" seals. SAMA 9 would no longer be cost beneficial.
10	Alter Ductwork Between the Aux Bldg Sump Drain Room and the SX Pump Room	This SAMA primarily protects the SX pumps, which in turn helps prevent RCP seal LOCAs. The DMS virtually eliminates the RCP seal LOCA contribution through the installation of "no-leak" seals. SAMA 10 would no longer be cost beneficial.
13	Alternate AFW Cooling with Seal Protection	This SAMA provides a heat removal mechanism that is not dependent on SX. The DMS provides the same capability. SAMA 13 would no longer be cost beneficial.
16	Install High Flow Sensors On the Non-Essential Service Water System	This SAMA primarily protects the SX pumps, which in turn helps prevent RCP seal LOCAs. The DMS virtually eliminates the RCP seal LOCA contribution through the installation of "no-leak" seals. SAMA 16 would no longer be cost beneficial.
19	Replace MOVs in the RHR Discharge Line with Valves that Can Isolate an ISLOCA Event	The DMS would not impact ISLOCA risk. SAMA 19 would remain a viable candidate for potential implementation.
22	Install the Same High Flow Isolation Logic Used on Valve _CC685 on Valve _CC9438	The DMS would not impact ISLOCA risk. SAMA 22 would remain a viable candidate for potential implementation.

Review of Impact of the DMS and AFW Cross-Tie on Cost Benefit Analysis

SAMA Number	SAMA Title	Discussion
25	Install a Filtered Containment Vent	After implementation of the DMS and SAMA 15, a factor of 10 reduction in the LATE-CHR-AFW and LATE-CHR-NOAFW dose-risk and offsite economic cost-risk is estimated to result in a reduction in the MACR from about \$8.4 million to \$6.7 million, which is an averted cost-risk of \$1.7 million. Even using the 95th percentile multiplier of 2.29, the averted cost-risk of about \$3.9 million is less than the estimated implementation cost of \$5,700,000. This SAMA would no longer be cost beneficial.
26	DMS Using a Dedicated Generator, Self-Cooled Charging Pump, and a Portable AFW Pump	This is an alternate approach to The DMS and it is considered to be obviated by implementation of SAMA 11.
27	Protect RH, SI, and CVCS Cubicle Cooling Fan Cables in Fire Zone 11.3-0	This SAMA protects cables that are used to support RCP seal cooling and heat removal via RH. The DMS includes "no-leak" seals that would prevent most seal LOCAs and preclude the need for RH while providing an alternate secondary side heat removal source. SAMA 27 would no longer be cost beneficial.
28	Install Fire Barriers around MCC 132X4	This SAMA addresses contributors related to RCP seal LOCAs, which are addressed by the DMS, but also scenarios that include failure to restore FW, which would not be impacted by the DMS due to human dependence issues. SAMA 28 is considered to remain a viable candidate for potential implementation.
29	Seal the Inverter 111 Panel and Install Fire Barriers to Protect Nearby Equipment	The DMS may require action in the area impacted by the relevant fire or depend on the equipment in the area. SAMA 29 may remain a viable candidate for potential implementation.
31	Install Fire Barriers around MCCs 132X5 and 134X	RCP seal LOCAs are a large contributor to the risk associated with the fires that damage the MCCs 132X5 and 134X. The DMS would mitigate these scenarios and SAMA 31 would no longer be a cost beneficial SAMA.
32	Install Fire Barriers around MCC 131X2	RCP seal LOCAs and AFW failures are large contributors to the risk associated with the fires that damage MCC 131X2. The DMS would mitigate these scenarios and SAMA 32 would no longer be a cost beneficial SAMA.

Review of Impact of the DMS and AFW Cross-Tie on Cost Benefit Analysis

SAMA Number	SAMA Title	Discussion
33	Unit 2 SAMA - Install Cable Wrap on the 141 to 241 4KV Cross-tie Cable in the Division 11 ESF Switchgear Room	These fires result in the loss of AFW and can potentially be mitigated by the DMS, but over 30 percent of the contributors are associated with failure to manually start AFW. Human dependence issues would limit the benefit of the DMS and this SAMA would remain a viable candidate for potentially implementation.
34	Unit 2 SAMA - Install Cable Wrap on the 141 to 241 4KV Cross-tie Cable in the Aux Building Elevation 426' of the General Area	The fires associated with SAMA 34 include scenarios with head vent LOCAs and AFW initiation failures, which limit the impact of the DMS. SAMA 34 may remain a viable candidate for potential implementation.
35	Unit 2 SAMA - Install Cable Wrap to Protect 2AF005A, B, C, and D in in the Division 21 Containment Electrical Penetrations Area	RCP seal LOCAs and AFW failures are consequences of the fires associated with SAMA 35. Implementing the DMS would help reduce these contributions and SAMA 35 would no longer be cost beneficial.

While a large number of SAMAs can be considered potentially cost beneficial for Braidwood when considered independently, there is a smaller subset of SAMAs that, if implemented, would render the remaining SAMAs “not cost beneficial”. This subset is SAMAs 5, 6, 7, 11, 15, 19, 22, 28, 29, 33, and 34[2].

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[2] Given that the fire model is in an interim state, the cost benefit analysis for SAMAs 28, 29, 33, and 34 should also be considered “interim” until the associated fire scenarios are further refined.

F.9 TABLES

Table F.2-1
Byron/Braidwood PRA Model Update History

Model Change description	Rev.	Date	CDF	LERF	Comments
Original IPE	---	BY-04/1994 BW-06/1994	3.09E-05 2.74E-05	2.73E-06 2.62E-06	Initial IPE submittal, which was conducted to satisfy GL 88-20 requirements. This study was based on the support-state model methodology.
Modified IPE	---				IPE safety evaluation report was received on this study, which satisfied GL 88-20 requirements.
Changed PRA model methodology and Updated all Data	0	10/1999	BY1-4.98E-05 BY2-4.88E-05 BW1-4.86E-05 BW2-4.86E-05	BY1-4.48E-06 BY2-4.35E-06 BW1-3.78E-06 BW2-3.81E-06	PRA model was changed from the support state model to linked fault tree method. The changes involved extensive modifications to all event trees and fault trees. All data, including initiating event frequencies, equipment failure data, common cause failure (CCF) data and human error probabilities were updated using most recent industry sources. Plant-specific data was also updated.
One SX pump criteria incorporated	1	10/2000	BY1-4.55E-05 BY2-4.45E-05 BW1-4.61E-05 BW2-4.60E-05	BY1-5.41E-06 BY2-5.33E-06 BW1-4.89E-06 BW2-4.89E-06	The SX pump success criteria were changed from two pumps to one pump.
LOOP/DLOOP Event Tree revised	2	06/2001	BY1-4.81E-05 BY2-4.80E-05 BW1-4.60E-05 BW2-4.59E-05	BY1-5.29E-06 BY2-5.27E-06 BW1-4.96E-06 BW2-4.96E-06	The event tree was revised to remove extensive cutset recoveries performed as post processing. Revision 2 of PRA model was documented as an interim model and was not released as a working model.

Table F.2-1
Byron/Braidwood PRA Model Update History

Model Change description	Rev.	Date	CDF	LERF	Comments
Internal flooding analysis revised and incorporation of plant mods to CV pump lube oil cooler	3	06/2001	BY1-5.56E-05 BY2-5.53E-05 BW1-3.15E-05 BW2-3.14E-05	BY1-6.26E-06 BY2-6.24E-06 BW1-4.65E-06 BW2-4.65E-06	Previous revisions did not include the results of internal flooding analysis. A fire hose connection from FP system to the CV pump lube oil cooler was made available as an alternate cooling water source. This mod removed a complete dependency of CV pumps on SX system. FP and VA system models were added as a result of this change.
Incorporated a plant mod at Byron (not applicable to Braidwood)	3a	08/2001	BY1-5.50E-05 BY2-5.48E-05 BW1-3.15E-05 BW2-3.14E-05	BY1-6.15E-06 BY2-6.13E-06 BW1-4.60E-06 BW2-4.60E-06	This mod included removal of automatic control of 1(2)SX173 and 1(2)SX178 air operated valves, which provide cooling water to AF pump 1B. This mod removed AF pump 1B dependency on Instrument Air.
RPS and CCW system logic revised	3b	Not Available	Not Available	Not Available	The changes include system logic enhancements and corrections identified during the previous PRA revision. The model revision was performed in support of Westinghouse Owners Group ATWS sensitivity study. This revision was not issued.
System Model and Containment Failure updates	4	02/2002	BY1-5.27E-05 BY2-5.20E-05 BW1-3.12E-05 BW2-3.12E-05	BY1-5.41E-06 BY2-6.15E-06 BW1-4.57E-06 BW2-4.93E-06	Made significant model enhancements to the following systems: reactor protection system (RPS), engineered safety features actuation system (ESFAS), CCW, PORVs, AFW and instrument power. The changes were system specific and included changes to address issues such as the need to remove instrument power for the PORVs for non-ATWS conditions, adding 3-of-4 common cause failure terms for the AF-005 valves, and the re-development of the RPS fault trees. Also, the Containment Failure likelihood was updated.

Table F.2-1
Byron/Braidwood PRA Model Update History

Model Change description	Rev.	Date	CDF	LERF	Comments
Inverter LCO AOT Extension	4B	10/2002	BY1-5.36E-05 BY2-5.26E-05 BW1-3.26E-05 BW2-3.24E-05	BY1-4.85E-06 BY2-5.49E-06 BW1-4.06E-06 BW2-4.31E-06	Modifications to support more efficient model updates in the future and other miscellaneous issues to support the 120VAC Inverter limiting condition for operation (LCO) AOT Extension Application. Multiple detailed modeling changes were performed to address known issues. For example, the small LOCA and transient accident modeling logic was changed, the pump signal modeling for CC, SX, and CV was changed, and the CCW fault tree was revised to update how the Unit 0 heat exchanger was credited.
Address miscellaneous model issues and updated data.	5	12/2002	BY1-4.91E-05 BY2-4.68E-05 BW1-3.84E-05 BW2-3.83E-05	BY1-4.41E-06 BY2-4.82E-06 BW1-4.20E-06 BW2-4.45E-06	Changed model to address several model issues and incorporate values from updated failure and unavailability data, operator action HEPs, and support system initiating event frequencies.
New SX Success Criteria and Loss of SX frequency. Address quality issues for periodic update.	5A	05/2003	BY1-6.43E-05 BY2-6.34E-05 BW1-5.78E-05 BW2-5.75E-05	BY1-4.93E-06 BY2-5.87E-06 BW1-5.04E-06 BW2-5.78E-06	Revised the model and data to address the PRA quality issues raised by CR#00142080 (1/30/03) against Rev. 5 model. Re-evaluated the plant-specific data, performed full convergence analysis and a human failure dependency analysis. Incorporated new SX success criteria. This model is used to support the SX technical specification (TS) CT (Completion Time) Extension (one-time relief) application.
Automatic Quantification using PSALink.	5B	06/2003	BY1-6.15E-05 BY2-6.06E-05 BW1-5.43E-05 BW2-5.39E-05	BY1-4.65E-06 BY2-5.52E-06 BW1-4.74E-06 BW2-5.39E-06	Revised the model so that automatic quantification can be performed using ORAM-Sentinel and PSALINK program.

Table F.2-1
Byron/Braidwood PRA Model Update History

Model Change description	Rev.	Date	CDF	LERF	Comments
Conditional LOOP events	5E	Not Available	BY1-5.79E-05 BY2-5.72E-05 BW1-5.46E-05 BW2-5.38E-05	BY1-4,72E-06 BY2-5.62E-06 BW1-4.99E-06 BW2-5.75E-06	Model revised to incorporate conditional dual unit loss of offsite power (LOOP) for most all initiators, updated some LERF binning, changed modeling of ESFAS testing, added RWST switchover channel testing and common cause. Other minor changes.
Incorporation of component spurious operation	5F	12/2006	BY1-5.75E-05 BY2-5.70E-05 BW1-5.42E-05 BW2-5.36E-05	BY1-4.71E-06 BY2-5.62E-06 BW1-4.98E-06 BW2-5.75E-06	Model revisions to the Byron/Braidwood PRA to deal with potential spurious operation of key components that were not accounted for in the full power internal events (FPIE) model in order to obtain more realistic results for the Braidwood Fire PRA activities.

Table F.2-1
Byron/Braidwood PRA Model Update History

Model Change description	Rev.	Date	CDF	LERF	Comments
Periodic Update	6	07/2007	BY1-5.9E-05 BY2-5.9E-05 BW1-3.1E-05 BW2-3.6E-05	BY1-3.2E-06 BY2-4.4E-06 BW1-2.9E-06 BW2-3.9E-06	Periodic Model Update. Model revisions included changes to AFW success criteria based on new MAAP 4.0 analyses, revisions to HEPs to reflect new procedure changes and operator interviews, revision of the flooding analysis based on HEP changes, incorporation of updated data analyses, explicit modeling of ISLOCA sequences, expansion of CCF treatment for Byron SX tower modeling, incorporation of modeling changes to allow for multiple SX or CC pumps and/or heat exchangers to be out of service online, addition of ventilation modeling for motor-driven AF pumps, correction of emergency boration logic, incorporation of the new Byron air compressor configuration, accounting for instrument bus auto transfer features (both installed and future modifications), incorporation of logic to require operators to start another CC pump or reduce loads if a CC pump fails after two RH heat exchangers are in service on one CC pump, addition of normally open manual valve in the SX system that may be closed for system maintenance or repair online, changes to the RPS logic to better reflect the signals that cause a trip relative to the initiators, changed AF auto start logic to include AMSAC signals, removed credit for the diesel-driven AF pump's SX booster pump on loss of SX events (such as CCF of all four strainers) that would result in flow blockage, and other issues in the Updating Requirement Evaluation (URE) database. Due to issues identified with this model, it was not considered a model of record.
RPS/ESFAS Application	6A	Not Available	Not Available	Not Available	An application specific model for RPS/ESFAS TS Change RAI Responses.

Table F.2-1
Byron/Braidwood PRA Model Update History

Model Change description	Rev.	Date	CDF	LERF	Comments
Error Correction	6B	02/2008	BY1-6.0E-05 BY2-6.0E-05 BW1-3.6E-05 BW2-3.6E-05	BY1-3.1E-06 BY2-4.3E-06 BW1-2.9E-06 BW2-3.4E-06	Addressed the issues identified in model revision 6 and other issues during review of the R6B model. Due to issues identified with merging the flood model with the base model, which were identified while incorporating new Byron flood mitigation procedures, this model was not considered a model of record.
Flood Procedures	6C	05/2008	BY1-3.6E-05 BY2-3.6E-05 BW1-3.6E-05 BW2-3.5E-05	BY1-2.5E-06 BY2-3.1E-06 BW1-2.9E-06 BW2-3.4E-06	Incorporated new Byron flood procedure in support of B/B RTS/ESFAS TS changes. Performed benchmark tests to switch over to CAFTA 5.3 and PRAQUANT 5.0a.
RCP Seal LOCA Model	6D	12/2008	BY1-2.2E-05 BY2-2.2E-05 BW1-2.3E-05 BW2-2.3E-05	BY1-2.1E-06 BY2-2.3E-06 BW1-2.5E-06 BW2-2.7E-06	Revised RCP seal LOCA model for non-LOOP sequences. Incorporated URE-709 (Bleed & Feed Success Criteria), 711 (logic error correction), 712 (Revised BE name) and 715 (Correction of a logic issue in the MLOC-05 sequence).
AF Crosstie	6E	06/2009	BY1-1.7E-05 BY2-1.7E-05 BW1-1.6E-05 BW2-1.5E-05	BY1-1.2E-06 BY2-1.5E-06 BW1-1.4E-06 BW2-1.6E-06	Incorporated AF Unit Crosstie Modification at Byron. The similar modification will be expected to be completed at Braidwood in October 2009. The HEP changes from HRA migration to HRA Calculator 4.0 were also implemented.
Software Revision	6E1	Not Available	BY1-1.7E-05 BY2-1.7E-05 BW1-1.6E-05 BW2-1.5E-05	BY1-1.1E-06 BY2-1.4E-06 BW1-1.4E-06 BW2-1.6E-06	Re-quantified the results using FORTE 3.0c due to a memory error encountered with FORTE 2.2f at the truncation limits of 1E-11 for CDF and 1E-12 for LERF for some application cases. No modeling changes.

Table F.2-1
Byron/Braidwood PRA Model Update History

Model Change description	Rev.	Date	CDF	LERF	Comments
Addendum to identify key operator actions	6E2	03/2010	BY1-1.7E-05 BY2-1.7E-05 BW1-1.6E-05 BW2-1.5E-05	BY1-1.1E-06 BY2-1.4E-06 BW1-1.4E-06 BW2-1.6E-06	Identified 12 operator actions as key assumptions to B/B PRA R6E1 model, based on the BB HRA. This was an addition to the model documentation and did not change or supersede the R6E1 model.
Addendum to revise software quantification engine	6E3	05/2010	BY1-1.7E-05 BY2-1.7E-05 BW1-1.6E-05 BW2-1.5E-05	BY1-1.1E-06 BY2-1.4E-06 BW1-1.4E-06 BW2-1.6E-06	Document the B/B PRA results using FTREX 1.5 to enable the use of FTREX for Byron/Braidwood risk applications. The PRA model R6E was not changed, and the results from R6E1 and R6E3 are identical.
CC Split-train operation and updated Internal Flooding Analysis	6F	09/2011	BY1-2.53E-05 BY2-2.56E-05 BW1-4.02E-05 BW2-3.88E-05	BY1-1.33E-06 BY2-1.83E-06 BW1-1.75E-06 BW2-2.22E-06	Unscheduled update to incorporate operator actions to split the CC trains under most conditions. This is expected to be a temporary condition until plant modifications are completed that will support a return to the assumed conditions where the CC trains are not normally split. Also includes ongoing working model changes and the updated internal flooding model.
2011 Periodic Update	BB011a	06/2012	BY1-4.17E-05 BY2-4.03E-05 BW1-4.26E-05 BW2-4.26E-05	BY1-2.57E-06 BY2-3.21E-06 BW1-2.67E-06 BW2-3.28E-06	Periodic Update, including new data analysis, new HRA dependency analysis, and new pre-initiator HRA. Nearly 400 UREs addressed. Model also removes credit for operator action to crosstie AFW. Model naming scheme modified to match new Exelon guidance.

Table F.2-1
Byron/Braidwood PRA Model Update History

Model Change description	Rev.	Date	CDF	LERF	Comments
2012 MSPI Update	BB011b	11/2012	BY1-3.97E-05 BY2-3.82E-05 BW1-3.57E-05 BW2-3.51E-05	BY1-2.55E-06 BY2-3.19E-06 BW1-2.52E-06 BW2-3.08E-06	Emergent model update with improved modeling of CC and SX to support improved mitigating systems performance index (MSPI) calculations. Model includes credit for a new operator action to manipulate SX007 valves on loss of power and a new recovery action to use the 0CC pump to provide decay heat removal in key sequences.
2012 Level 2 Update	BB011b1	12/2012	BY1-3.97E-05 BY2-3.82E-05 BW1-3.57E-05 BW2-3.51E-05	BY1-1.07E-06 BY2-1.02E-06 BW1-1.05E-06 BW2-1.04E-06	This is an application specific model that was developed to support the SAMA analysis.. The LERF model was replaced with a Level 2 Model based on the methodology in WCAP-16341-P.

Table F.2-2
Braidwood PRA Top Ranking Accident Sequences to CDF

Sequence ID	Accident Sequence Description	Contribution to CDF
SLOC-09	Small LOCA with failure of High Pressure Injection via Charging Pumps and Safety Injection Pumps. This sequence is dominated by induced RCP Seal LOCAs, primarily from Loss of SX and internal flood initiators. Operator actions which contribute to this sequence are failure to open the SX crosstie, failure to align FP for CV pump cooling, and failure to isolate internal flood initiators. Dependent operator actions related to Loss of SX are key contributors.	19-21%
TRAN-04	Transient with failure of all feed to the Steam Generators and failure to establish ECCS high pressure recirculation cooling after successful high pressure injection via the charging pumps. The dominant initiating events associated with this sequence are Loss of SX and internal flooding scenarios. The key operator actions which contribute to this sequence are failure to restore feedwater from the main feedwater pumps and failure to establish the AFW cross-tie.	20%
SLOC-02	Small LOCA with failure to establish ECCS recirculation cooling and successful cooldown and depressurization. Essentially all of this sequence is due to random non-isolable small LOCAs. Induced RCP Seal LOCAs are negligible contributors. Failure of the SX007 valves to be throttled to their post-accident position increases the importance of this sequence at Braidwood. Another important operator action which contributes to this sequence is failure to secure the RH pumps in the mini-flow mode (resulting in their failure).	17-18%
SLOC-18	Small LOCA with failure of High Pressure Injection via Charging Pumps and Safety Injection Pumps; AF fails, but Steam Generators are fed from the Motor Driven or Startup Feedwater Pump. LOCAs for this sequence are due to Loss of SX or internal flood initiators. Key operator actions that contribute to this sequence are failures to isolate internal floods in time to prevent failure of the SX pumps and failure to recover RCP seal cooling.	16%
SLOC-06	Small LOCA with failure to establish ECCS recirculation cooling and successful cooldown and depressurization. Most of this sequence is due to RCP Seal LOCAs following a Loss of CCW. The dominant operator action which contributes to this sequence is failure to align the CV pump to a cool suction source.	9%
MLOC-03	Medium LOCA with failure of High and Low Head Recirculation. This sequence is dominated by failure of the SX007 valves to be throttled to their post-accident position.	4%
SGTR-04	Steam Generator Tube Rupture with failure to cooldown and depressurize the primary system. Risk from this sequence is dominated by the dependent human actions to cooldown the RCS and terminate the break flow.	3%

Table F.2-2
Braidwood PRA Top Ranking Accident Sequences to CDF

Sequence ID	Accident Sequence Description	Contribution to CDF
TRAN-05	This is a transient with failure of Auxiliary Feedwater and failure of Motor Driven and Startup Feedwater Pumps. HPI is provided by the Centrifugal Charging Pumps (CCPs), but feed and bleed fails due to failure of the PORVs to open due to operator failure.	3%
TRAN-09	This is a transient with failure of Auxiliary Feedwater, failure of Motor Driven and Startup Feedwater Pumps, and failure to establish Bleed and Feed using Charging Pumps and Safety Injection Pumps. The key initiating events associated with this sequence are Loss of SX and internal flooding. The SX pumps are the most risk significant components in this sequence. Operator actions which contribute to this sequence are failure to establish feedwater from the main feedwater system and failure to mitigate internal flooding events.	2%
LOOP-65	Station Blackout (SBO) with failure of all AFW. Offsite power is recovered prior to core damage and High Pressure Injection is established, but ECCS recirculation fails. The dominant initiating event is a Loss of SX followed by a consequential LOOP. Without SX cooling, there is no way to remove decay heat.	2%
SLOC-25	Small LOCA with failure of all feedwater and high pressure injection. Key initiating events include Loss of SX and internal flooding. Key operator actions include recovery from the Loss of SX and mitigation of the flooding events.	1%
SGTR-03	Steam Generator Tube Rupture with failure of shutdown cooling. Risk from this sequence is dominated by a variety of human actions to cooldown the RCS, throttle the SX007 valves, establish shutdown cooling, reduce ECCS injection, and stop the RH pumps while on miniflow.	1%
LODC-03	Loss of the 125VDC bus with failure of all feed to the Steam Generators and failure to establish ECCS high pressure recirculation cooling after successful high pressure injection via the charging pumps. The initiating event associated with this sequence is Loss of the 111/211 bus. The key operator actions which contribute to this sequence are failure to establish the AFW cross-tie, failure to establish high pressure recirculation, and failure to throttle the SX007 valves.	1%

Table F.2-3
Braidwood Important Operator Actions Based on CDF

Important Operator Actions	Important Sequences/Scenarios
Throttle open SX007 valves (19% of CDF)	For any scenario where decay heat removal by the RH heat exchangers and/or RH pump cooling is needed, the CC heat exchangers are needed, which require throttling open of the SX007 valve to its accident position. This is required for all LOCA scenarios, including induced LOCAs through the PORV, RCP Seal LOCAs, and bleed and feed operation.
Joint action to start a standby pump, establish an SX crosstie, and provide cooling to the CV pumps following loss of SX (16% of CDF)	This is a joint event representing the failure of operators to first fail to start a standby pump (typically SX), followed by failure to crosstie SX. Without SX, RCP seal cooling will be lost unless the CV pumps can be provided with cooling from the FP system and a cool suction source. The third failure in this combination fails that cooling to the CV pumps.
Recover SX crosstie between units (14% of CDF)	Upon Loss of SX, operators need to recover SX by establishing the SX crosstie to the opposite unit. If no RCP seal failure occurs, a later chance to recover the crosstie is credited, which is modeled by this action.
Align CV pump suction to RWST upon loss of SX (10% of CDF)	Upon Loss of SX, cooling to the CV pumps must be established by aligning FP and realigning the CV pump suction to use the RWST as a cool suction source. Failing to do so results in loss of seal injection to the RCP(s). Loss of SX also fails the CC system that fails RCP Thermal Barrier Cooling. This has a high probability of leading to an RCP Seal LOCA.
Recover FP cooling to CV pumps for FP internal flood (10% of CDF)	This action models the recovery of FP cooling to the CV pumps for the purposes of high pressure injection following an FP internal flood where seal injection was previously lost. It is not credited if the FP piping break occurred in a location which prevent recovery or if the RCP seals fail and lead to a large Seal LOCA.
Restore feedwater as a source of secondary side cooling (9% of CDF)	Upon failure of AFW to provide cooling water to the steam generators, operators have the opportunity to utilize the main feedwater or startup feedwater pumps to provide another source of feedwater. Failure results in a complete loss of feedwater to the steam generators. This is exacerbated by the current loss of credit for the AFW crosstie.
Mitigate FP Internal Flood Event (7% of CDF)	Following a Fire Protection System rupture in the Aux Building, operators need to terminate the flooding event (requires turning off the Diesel Driven FP Pump at the Lake Screen House) to prevent flood damage to the SX system or need to align alternate cooling to the CV pumps to maintain RCS inventory control. Failure leads to a Loss of all RCP Seal Cooling and a high probability of an RCP Seal LOCA which can't be mitigated due to the loss of the SX pumps and other essential equipment in the Aux Building.

Table F.2-4
Mapping of Level 1 Sequences to PDS

CDF Seq. ID	PDS	CDF Seq. ID	PDS	CDF Seq. ID	PDS	CDF Seq. ID	PDS	CDF Seq. ID	PDS	CDF Seq. ID	PDS
ATWS-02	NHA	LODC-05	NHN	LOOP-36	NHN	LOOP-65	NHN	SGTR-25	B-N	SLOC-04	NHA
ATWS-04	NHA	LOOP-04	NHA	LOOP-37	NHN	LOOP-66	NHN	SGTR-27	B-N	SLOC-06	NHA
ATWS-06	NHA	LOOP-05	NHA	LOOP-39	NHA	LOOP-67	NHN	SGTR-28	B-N	SLOC-08	NHA
ATWS-07	NHN	LOOP-07	NHA	LOOP-40	NHA	LOOP-68	NHN	SGTR-29	B-N	SLOC-09	NHA
ATWS-08	NHA	LOOP-08	NHA	LOOP-42	NHN	LOOP-69	NHN	SGTR-30	BHA	SLOC-11	NHA
ATWS-10	NHA	LOOP-10	NHN	LOOP-43	NHN	MLOC-03	NLN	SLBI-03	NHN	SLOC-13	NHA
ATWS-11	NHA	LOOP-11	NHN	LOOP-44	NHN	MLOC-04	NLA	SLBI-04	NHN	SLOC-15	NHA
ATWS-13	NHA	LOOP-12	NHN	LOOP-46	NHN	SGTR-03	B-A	SLBI-05	NHN	SLOC-17	NHA
ATWS-14	NHA	LOOP-16	NHA	LOOP-47	NHN	SGTR-04	B-A	SLBI-07	NHN	SLOC-18	NHA
ATWS-15	NHN	LOOP-17	NHA	LOOP-48	NHN	SGTR-06	B-A	SLBI-08	NHN	SLOC-20	NHN
ATWS-16	NHA	LOOP-20	NHA	LOOP-50	NHN	SGTR-07	B-A	SLBI-10	NHN	SLOC-21	NHN
1ILOC-01	B--	LOOP-21	NHA	LOOP-51	NHN	SGTR-10	B-A	SLBI-11	NHN	SLOC-23	NHN
1ILOC-02	B--	LOOP-23	NHA	LOOP-52	NHN	SGTR-11	B-A	SLBI-12	NHN	SLOC-24	NHN
1ILOC-03	B--	LOOP-24	NHA	LOOP-54	NHA	SGTR-13	B-A	SLBI-13	NHN	SLOC-25	NHN
1ILOC-04	B--	LOOP-26	NHA	LOOP-55	NHA	SGTR-14	B-A	SLBO-03	NHN	SLOC-26	NHN
1ILOC-05	B--	LOOP-27	NHA	LOOP-56	NHA	SGTR-15	B-A	SLBO-04	NHN	TRAN-04	NHN
LLOC-02	NLA	LOOP-29	NHA	LOOP-58	NHA	SGTR-18	B-A	SLBO-05	NHN	TRAN-05	NHN

Table F.2-4
Mapping of Level 1 Sequences to PDS

CDF Seq. ID	PDS	CDF Seq. ID	PDS	CDF Seq. ID	PDS	CDF Seq. ID	PDS	CDF Seq. ID	PDS	CDF Seq. ID	PDS
LLOC-03	NLA	LOOP-31	NHN	LOOP-59	NHA	SGTR-19	B-A	SLBO-07	NHN	TRAN-07	NHN
LLOC-04	NLA	LOOP-32	NHN	LOOP-60	NHA	SGTR-21	B-A	SLBO-08	NHN	TRAN-08	NHN
LODC-03	NHN	LOOP-33	NHN	LOOP-62	NHA	SGTR-22	B-A	SLBO-09	NHN	TRAN-09	NHN
LODC-04	NHN	LOOP-35	NHN	LOOP-63	NHA	SGTR-24	B-N	SLOC-02	NHA	XLOC-00	NLA

Table F.2-5
Correlation of PDS to Sequences

L2 Sequence	NHA	NHN	NLA	NLN	B--	B-A	BHA	B-N
Intact01			X	X				
Intact02	X							
Intact03		X						
Intact04		X						
Intact05		X						
Late01			X	X				
Late02			X	X				
Late03			X	X				
Late04	X							
Late05	X							
Late06	X							
Late07		X						
Late06		X						
Late07		X						
Late08		X						
Late09		X						
Late10		X						
Late11		X						
Late12		X						
Late13		X						
Late14		X						
Late15		X						
Late16		X						
LERF01			X	X				
LERF02	X							
LERF03		X						

Table F.2-5
Correlation of PDS to Sequences

L2 Sequence	NHA	NHN	NLA	NLN	B--	B-A	BHA	B-N
LERF04		X						
LERF05		X						
LERF06		X						
LERF07		X						
LERF08		X						
LERF09	X	X	X	X				
LERF10						X	X	
LERF11					X			X
SERF01		X						
SERF02						X	X	

Table F.2-6
Representative Sequences

Release Category	Dominant L2 Sequences	Representative Sequence Discussion
LERF-ISLOCA	LERF11-ISLOCA: 100%	The Level 1 1ILOC-03 sequence is the dominant contributor and is used to characterize the release category. This sequence is a break in the RHR discharge line outside containment followed by successful injection, but core damage ensues as there is no water in the sump for recirculation mode. ILOC-04, the other top contributor, is similar, but the break is in the RHR suction line. ISLOCA in the RHR discharge line (800 gpm break), successful scram, successful injection, recirculation unavailable, core damage, containment bypass.
LERF-CI	LERF09: 100%	There are many different contributions to this release category due to its inclusive nature, but a vast majority includes failure of the recirculation mode after successful injection. Approximately 60% of the total contribution comes from small LOCA scenarios (both small LOCA initiators and RCP seal LOCAs that evolve from other initiating events). The remaining 40% is comprised mostly of loss of SX and Flooding events. Medium LOCAs are small contributors and are almost all recirculation failures. A truly representative sequence for this release category would be a small LOCA with recirculation failure, but to address the faster evolving contributors with injection failures, the seal LOCA with F&B failure is used. Loss of SX, successful scram, RCP seal LOCA, injection failure, core damage, containment isolation failure.
LERF-CFE	LERF02: 69% LERF03: 26%	The main difference between sequences LERF02 and LERF03 with respect to equipment availability is that AFW is available for LERF02 while it is not for LERF03. Both sequences include a mixture of injection and recirculation failures. Because LERF03 scenarios may evolve more quickly, they are used as the representative sequence as injection failure cases. Loss of SX, successful scram, no AFW, FW not restored, seal cooling successful, operator fail to initiate feed and bleed injection, core damage, successful operator action to depressurize the RCS prior to vessel failure or tube rupture, vessel melt, and containment failure due to hydrogen burn.

Table F.2-6
Representative Sequences

Release Category	Dominant L2 Sequences	Representative Sequence Discussion
LERF-SGTR-AFW	LERF10: 100%	About 75% of the contributors are the result of operator failure to cool down the RCS in time to prevent passing water through the SG PORVs followed by operator failure to cool down the RCS to terminate SGTR break flow before RWST depletion. An additional 10% of the contribution is from failure to cool down the RCS in time to prevent passing water through the SG PORVs followed by operator failure to failure to throttle SX007 for recirculation. The consequences of these scenarios are similar and the larger contributor is chose as representative. SGTR, successful scram, SG isolation successful, failure to cool down RCS before passing water through the SG PORV, stuck open SG PORV, RCS injection successful, failure to cool down the RCS before RWST depletion, core damage, release through tubes.
LERF-SGTR-NOAFW	LERF11: 100%	The contributing scenarios are dominated by common cause failure of AFW followed by failure to restore main feedwater (MFW). SGTR, scram successful, AFW fails, FW not restored, injection successful, RWST depletes, core damage, release through tubes.
LERF-ISGTR	LERF08: ~99% LERF07: ~1%	Most of the induced tube rupture scenarios are pressure induced tube ruptures (LERF08), but thermally induced ruptures (LEFF07) are also represented in the cutsets. The TI-SGTR contribution to LERF is small relative to the PI-SGTR due to likelihood of hot leg failure near the time of TI-SGTR (eliminates release pathway). Both scenarios, however, are dominated by transient initiators with AFW unavailability, most of which lead to recirculation failures. Feed and Bleed failures are smaller contributors, but because of the potential impact on the source terms, the Feed and Bleed failure scenario is chosen as the representative case. Loss of SW, successful scram, AFW unavailable, operators fail to align alt FW and fail to align F&B, core damage, pressure induced tube rupture occurs.

Table F.2-6
Representative Sequences

Release Category	Dominant L2 Sequences	Representative Sequence Discussion
LATE-BMT-AFW	LATE04: ~81% LATE01: ~13%	For both the LATE04 and LATE01 sequences, most of the contributors are LOCA events (including seal LOCAs) with recirculation failures. The availability of water on the containment floor impacts the probability of the basemat meltthrough, but has a negligible impact on the source term itself. For the basemat failure releases, the differences in LOCA size also have a minimal impact on the results. The largest frequency contributor is chosen as the representative sequence, which are the small LOCAs. Small LOCA, successful scram, AFW available, injection successful, recirculation mode failure, core damage, containment heat removal success (RCFCs), CS success, basemat melt through.
LATE-BMT-NOAFW	LATE07: ~89% LATE08: ~11%	The difference in the two dominant Level 2 sequences is related to operation of Containment Spray, which determines if there is a water pool in the reactor cavity when the core relocates to the containment. The scenarios for both sequences are essentially the same, most being transients with AFW failure followed by a mixture of either injection or recirculation mode failures. For this case, the scenarios with the feed and bleed failures are chosen as representative to capture any potential timing issues for evacuation. General transient event, successful scram, AFW CCF to run, failure to restore FW, failure to initiate feed and bleed, core damage, no PI-SGTR, op depressurizes late, no early containment failure at vessel breach, containment heat removal (CHR) successful, CS successful, basemat failure.
LATE-CHR-AFW	LATE06: >99.9%	Late06 accounts for almost all of the contributions to this release category frequency. Over 92% of the contribution to the release category is from LOSW events or events that lead to SX failure, followed by a seal LOCA. The other contributions are almost all scenarios that result in a seal LOCA in a different manner. Recirculation and injection failures are both represented, but most are injection failures. LOSW, successful scram, AFW failed, startup FW OK, failure to align alternate seal cooling, failure to align SX X-tie, seal LOCA, injection failure, core damage, no containment failure at vessel breach (VB), CHR fails with long term containment overpressurization (COP).

Table F.2-6
Representative Sequences

Release Category	Dominant L2 Sequences	Representative Sequence Discussion
LATE-CHR-NOAFW	LATE09: >99%	Late09 accounts for almost all of the contributions to this release category frequency. Over 96% of the release category frequency is from LOSW events or events that lead to SX failure. These are generally followed by the unavailability of FW/Condensate and recirculation mode; injection failures contribute less than 10% of the frequency. LOSW (all SX pumps CCF), successful scram, AFW failure from lack of SW cooling, failure to restore FW, SX X-tie not available, CHR not available for recirc, core damage, operator depressurizes late, no containment failure at VB, CHR fails with long term COP.
SERF-SGTR -TISGTR-HLF	SERF01: 100%	The SERF01 sequence is comprised of mostly feed and bleed failures with some recirculation failures after failure of AFW. The more rapidly evolving feed and bleed failures are chosen as the representative sequences. Loss of 125 DC bus 111, successful scram, failure of AFW, failure of feed and bleed, core damage, late depressurization failure, TI-SGTR occurs, Hot leg fails at about the same time as TI-SGTR, no early containment failure, CHR success, CS success, no basemat failure.

Table F.2-6
Representative Sequences

Release Category	Dominant L2 Sequences	Representative Sequence Discussion
SERF-SGTR-AFW-SC	SERF02: 100%	The SERF02 sequence is mostly comprised (65% based on the Unit 2 results that correctly include 2RX-JHEP33-HOADA) of SGTR events with failure the operators to cool down the RCS before overfilling the SG (opens a steam generator PORV for a LOCA) and subsequent operator error to cool down the RCS to terminate the break flow before depleting the RWST. An additional 8% of the contribution is related to operator failure to throttle the 0SX007 valve during transition to recirculation after a successful break termination. The cases including 2RX-JHEP33-HOADA (about 8%) are SGTR events with operator failures to shut down dead headed RHR pumps (fails RH) and failure to reduce ECCS injection (to prevent lifting the SG safety valves). SGTR, successful scram, operator fails to cool down the RCS, SG overfill causes stuck open PORV, operator fails to cool down the RCS to terminate break flow before the RWST is depleted, recirculation mode is unavailable, core damage, operators maintain SG level over the top of the SG tubes for release scrubbing.
INTACT	INTACT02: ~75% INTACT03: ~14% INTACT01: ~11%	Most of the intact contribution comes from small LOCA scenarios (including induced Small LOCAs) with recirculation failures. For intact containment scenarios, the path to core damage has a negligible impact on the source term. Small LOCA, successful scram, AFW available, injection successful, recirculation failure, core damage, containment intact.

Table F.2-7
Braidwood Source Term Summary

	Release Category												
	LERF-ISLOCA	LERF-CI	LERF-CFE	LERF-SGTR-AFW(1)	LERF-SGTR-NOAFW	LERF-ISGTR	LATE-BMT-AFW(2)	LATE-BMT-NOAFW	LATE-CHR-AFW(3)	LATE-CHR-NOAFW(4)	SERF-SGTR-TISGTR-HLF	SERF-SGTR-AFW-SC(5)	INTACT
MAAP Case	1a	2a	3a	4a	5a	6a	7a	8a	9a	10a	11a	12b	13a
Run Duration	72 hr	72 hr	72 hr	200 hr	200 hr	800 hr	144 hr	144 hr	200 hrs	1600 hrs	72 hrs	200 hrs	72 hrs
Time after Scram when GE is declared	6.91	5.93	3.16	87.00	0.50	3.16	12.17	3.14	5.93	3.14	3.17	84.60	12.17
Fission Product Group:													
1) Noble													
Total Release Fraction	1.00E+00	9.80E-01	1.00E+00	8.10E-01	3.00E-01	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	5.10E-01	7.90E-01	2.70E-03
Total Plume 1 Release Fraction	9.70E-1	4.30E-1	9.10E-1	4.40E-1	2.70E-1	5.00E-2	2.00E-4	4.00E-4	4.00E-3	7.00E-2	5.10E-1	4.20E-1	3.00E-4
Start of Plume 1 Release (hr)	7.00	6.00	5.00	87.00	24.00	3.50	12.50	3.40	6.00	3.50	3.50	85.00	12.40
End of Plume 1 Release (hr)	8.00	11.00	8.00	89.00	25.00	4.50	17.00	13.00	9.00	13.50	4.00	87.00	18.00
Total Plume 2 Release Fraction	3.00E-2	5.00E-1	9.00E-2	8.00E-2	0.00E+0	9.50E-1	4.50E-3	3.90E-3	9.96E-1	9.30E-1	0.00E+0	1.30E-1	4.00E-4
Start of Plume 2 Release (hr)	8.00	11.00	8.00	89.00	25.00	17.00	17.00	13.00	60.75	36.50	4.00	87.00	18.00
End of Plume 2 Release (hr)	12.00	21.00	13.00	93.00	35.00	27.00	27.00	23.00	70.75	46.50	14.00	93.00	28.00
Total Plume 3 Release Fraction	0.00E+0	5.00E-2	0.00E+0	2.90E-1	3.00E-2	0.00E+0	9.95E-1	9.96E-1	0.00E+0	0.00E+0	0.00E+0	2.40E-1	2.00E-3
Start of Plume 3 Release (hr)	12.00	30.00	19.00	93.00	35.00	90.00	90.00	90.00	90.00	90.00	14.00	93.00	28.00
End of Plume 3 Release (hr)	22.00	40.00	29.00	98.00	45.00	100.00	100.00	95.00	100.00	100.00	24.00	95.00	38.00
2) CsI													
Total Release Fraction	7.80E-01	1.40E-02	3.00E-01	9.70E-02	4.10E-02	1.90E-01	6.80E-05	7.40E-04	1.40E-02	2.40E-01	5.80E-02	1.80E-02	3.20E-05

Table F.2-7
Braidwood Source Term Summary

	Release Category												
	LERF-ISLOCA	**LERF-CI**	**LERF-CFE**	**LERF-SGTR-AFW(1)**	**LERF-SGTR-NOAFW**	**LERF-ISGTR**	**LATE-BMT-AFW(2)**	**LATE-BMT-NOAFW**	**LATE-CHR-AFW(3)**	**LATE-CHR-NOAFW(4)**	**SERF-SGTR-TISGTR-HLF**	**SERF-SGTR-AFW-SC(5)**	**INTACT**
MAAP Case	1a	2a	3a	4a	5a	6a	7a	8a	9a	10a	11a	12b	13a
Run Duration	72 hr	72 hr	72 hr	200 hr	200 hr	800 hr	144 hr	144 hr	200 hrs	1600 hrs	72 hrs	200 hrs	72 hrs
Time after Scram when GE is declared	6.91	5.93	3.16	87.00	0.50	3.16	12.17	3.14	5.93	3.14	3.17	84.60	12.17
Fission Product Group:													
Total Plume 1 Release Fraction	7.10E-1	9.00E-3	1.40E-1	5.30E-2	3.80E-2	1.00E-3	2.70E-5	2.00E-5	2.00E-5	2.00E-4	5.80E-2	9.00E-3	2.70E-5
Start of Plume 1 Release (hr)	7.00	6.00	5.00	87.00	24.00	3.50	12.50	3.40	6.00	3.50	3.50	85.00	12.40
End of Plume 1 Release (hr)	8.00	11.00	8.00	89.00	25.00	4.50	17.00	13.00	9.00	13.50	4.00	87.00	18.00
Total Plume 2 Release Fraction	2.00E-2	3.00E-3	1.30E-1	3.00E-3	2.00E-3	1.10E-1	7.00E-6	5.00E-5	7.00E-3	1.30E-1	0.00E+0	0.00E+0	2.00E-6
Start of Plume 2 Release (hr)	8.00	11.00	8.00	89.00	25.00	17.00	17.00	13.00	60.75	36.50			18.00
End of Plume 2 Release (hr)	12.00	21.00	13.00	93.00	35.00	27.00	27.00	23.00	70.75	46.50			28.00
Total Plume 3 Release Fraction	5.00E-2	2.00E-3	3.00E-2	4.10E-2	1.00E-3	7.90E-2	3.40E-5	6.70E-4	7.00E-3	1.10E-1	0.00E+0	9.00E-3	3.00E-6
Start of Plume 3 Release (hr)	12.00	30.00	19.00	93.00	35.00	90.00	90.00	90.00	90.00	90.00		93.00	28.00
End of Plume 3 Release (hr)	22.00	40.00	29.00	98.00	45.00	100.00	100.00	95.00	100.00	100.00		95.00	38.00
3) TeO2													
Total Release Fraction	7.10E-01	1.90E-02	1.10E-01	6.30E-02	3.30E-02	2.00E-01	2.90E-05	1.10E-04	8.70E-05	1.10E-01	4.40E-02	9.50E-03	3.00E-05
Total Plume 1 Release Fraction	6.20E-1	1.60E-2	6.00E-2	3.80E-2	3.20E-2	1.00E-3	2.60E-5	2.00E-5	8.00E-6	1.00E-4	4.30E-2	5.40E-3	2.60E-5

Table F.2-7
Braidwood Source Term Summary

	Release Category												
	LERF-ISLOCA	LERF-CI	LERF-CFE	LERF-SGTR-AFW(1)	LERF-SGTR-NOAFW	LERF-ISGTR	LATE-BMT-AFW(2)	LATE-BMT-NOAFW	LATE-CHR-AFW(3)	LATE-CHR-NOAFW(4)	SERF-SGTR-TISGTR-HLF	SERF-SGTR-AFW-SC(5)	INTACT
MAAP Case	1a	2a	3a	4a	5a	6a	7a	8a	9a	10a	11a	12b	13a
Run Duration	72 hr	72 hr	72 hr	200 hr	200 hr	800 hr	144 hr	144 hr	200 hrs	1600 hrs	72 hrs	200 hrs	72 hrs
Time after Scram when GE is declared	6.91	5.93	3.16	87.00	0.50	3.16	12.17	3.14	5.93	3.14	3.17	84.60	12.17
Fission Product Group:													
Start of Plume 1 Release (hr)	7.00	6.00	5.00	87.00	24.00	3.50	12.50	3.40	6.00	3.50	3.50	85.00	12.40
End of Plume 1 Release (hr)	8.00	11.00	8.00	89.00	25.00	4.50	17.00	13.00	9.00	13.50	4.00	87.00	18.00
Total Plume 2 Release Fraction	5.00E-2	2.00E-3	3.00E-2	1.00E-3	0.00E+0	1.19E-1	1.00E-6	1.00E-5	3.30E-5	1.30E-3	1.00E-3	2.00E-4	3.00E-6
Start of Plume 2 Release (hr)	8.00	11.00	8.00	89.00		17.00	17.00	13.00	60.75	36.50	4.00	87.00	18.00
End of Plume 2 Release (hr)	12.00	21.00	13.00	93.00		27.00	27.00	23.00	70.75	46.50	14.00	93.00	28.00
Total Plume 3 Release Fraction	4.00E-2	1.00E-3	2.00E-2	2.40E-2	1.00E-3	8.00E-2	2.00E-6	8.00E-5	4.60E-5	1.09E-1	0.00E+0	3.90E-3	1.00E-6
Start of Plume 3 Release (hr)	12.00	30.00	19.00	93.00	35.00	90.00	90.00	90.00	90.00	90.00		93.00	28.00
End of Plume 3 Release (hr)	22.00	40.00	29.00	98.00	45.00	100.00	100.00	95.00	100.00	100.00		95.00	38.00
4) SrO													
Total Release Fraction	1.10E-01	3.00E-04	3.00E-03	9.90E-03	1.60E-04	7.90E-04	3.20E-06	2.90E-06	3.00E-05	2.60E-04	8.50E-05	8.00E-04	3.20E-07
Total Plume 1 Release Fraction	9.60E-02	2.30E-4	2.60E-3	1.00E-3	7.00E-5	1.00E-5	1.60E-6	2.20E-6	2.00E-8	2.00E-6	8.40E-5	1.50E-4	2.80E-7
Start of Plume 1 Release (hr)	7.00	6.00	5.00	87.00	24.00	3.50	12.50	3.40	6.00	3.50	3.50	85.00	12.40
End of Plume 1 Release (hr)	8.00	11.00	8.00	89.00	25.00	4.50	17.00	13.00	9.00	13.50	4.00	87.00	18.00

Table F.2-7
Braidwood Source Term Summary

	Release Category												
	LERF-ISLOCA	**LERF-CI**	**LERF-CFE**	**LERF-SGTR-AFW(1)**	**LERF-SGTR-NOAFW**	**LERF-ISGTR**	**LATE-BMT-AFW(2)**	**LATE-BMT-NOAFW**	**LATE-CHR-AFW(3)**	**LATE-CHR-NOAFW(4)**	**SERF-SGTR-TISGTR-HLF**	**SERF-SGTR-AFW-SC(5)**	**INTACT**
MAAP Case	1a	2a	3a	4a	5a	6a	7a	8a	9a	10a	11a	12b	13a
Run Duration	72 hr	72 hr	72 hr	200 hr	200 hr	800 hr	144 hr	144 hr	200 hrs	1600 hrs	72 hrs	200 hrs	72 hrs
Time after Scram when GE is declared	6.91	5.93	3.16	87.00	0.50	3.16	12.17	3.14	5.93	3.14	3.17	84.60	12.17
Fission Product Group:													
Total Plume 2 Release Fraction	5.00E-03	3.00E-5	1.00E-4	2.10E-3	9.00E-5	7.80E-4	1.50E-6	1.00E-7	3.00E-8	5.00E-6	1.00E-6	1.70E-4	3.00E-8
Start of Plume 2 Release (hr)	8.00	11.00	8.00	89.00	25.00	17.00	17.00	13.00	60.75	36.50	4.00	87.00	18.00
End of Plume 2 Release (hr)	12.00	21.00	13.00	93.00	35.00	27.00	27.00	23.00	70.75	46.50	14.00	93.00	28.00
Total Plume 3 Release Fraction	0.00	4.00E-5	3.00E-4	6.80E-3	0.00E+0	0.00E+0	1.00E-7	6.00E-7	3.00E-5	2.53E-4	0.00E+0	4.80E-4	1.00E-8
Start of Plume 3 Release (hr)		30.00	19.00	93.00			90.00	90.00	90.00	90.00		93.00	28.00
End of Plume 3 Release (hr)		40.00	29.00	98.00			100.00	95.00	100.00	100.00		95.00	38.00
5) MoO2													
Total Release Fraction	1.50E-01	1.70E-03	3.40E-02	4.60E-02	2.80E-03	3.30E-04	4.80E-06	1.20E-05	2.10E-06	1.20E-04	7.20E-03	4.60E-03	2.40E-06
Total Plume 1 Release Fraction	1.10E-1	1.60E-3	3.30E-2	2.10E-2	2.50E-3	4.00E-5	4.70E-6	1.20E-5	1.30E-6	4.00E-5	7.10E-3	3.10E-3	2.10E-6
Start of Plume 1 Release (hr)	7.00	6.00	5.00	87.00	24.00	3.50	12.50	3.40	6.00	3.50	3.50	85.00	12.40
End of Plume 1 Release (hr)	8.00	11.00	8.00	89.00	25.00	4.50	17.00	13.00	9.00	13.50	4.00	87.00	18.00
Total Plume 2 Release Fraction	4.00E-2	1.00E-4	1.00E-3	4.00E-3	3.00E-4	2.90E-4	1.00E-7	0.00E+0	8.00E-7	8.00E-5	1.00E-4	3.00E-4	2.00E-7

Table F.2-7
Braidwood Source Term Summary

	Release Category												
	LERF-ISLOCA	**LERF-CI**	**LERF-CFE**	**LERF-SGTR-AFW(1)**	**LERF-SGTR-NOAFW**	**LERF-ISGTR**	**LATE-BMT-AFW(2)**	**LATE-BMT-NOAFW**	**LATE-CHR-AFW(3)**	**LATE-CHR-NOAFW(4)**	**SERF-SGTR-TISGTR-HLF**	**SERF-SGTR-AFW-SC(5)**	**INTACT**
MAAP Case	1a	2a	3a	4a	5a	6a	7a	8a	9a	10a	11a	12b	13a
Run Duration	72 hr	72 hr	72 hr	200 hr	200 hr	800 hr	144 hr	144 hr	200 hrs	1600 hrs	72 hrs	200 hrs	72 hrs
Time after Scram when GE is declared	6.91	5.93	3.16	87.00	0.50	3.16	12.17	3.14	5.93	3.14	3.17	84.60	12.17
Fission Product Group:													
Start of Plume 2 Release (hr)	8.00	11.00	8.00	89.00	25.00	17.00	17.00		60.75	36.50	4.00	87.00	18.00
End of Plume 2 Release (hr)	12.00	21.00	13.00	93.00	35.00	27.00	27.00		70.75	46.50	14.00	93.00	28.00
Total Plume 3 Release Fraction	0.00E+0	0.00E+0	0.00E+0	2.10E-2	0.00E+0	0.00E+0	0.00E+0	0.00E+0	0.00E+0	0.00E+0	0.00E+0	1.20E-3	1.00E-7
Start of Plume 3 Release (hr)				93.00								93.00	28.00
End of Plume 3 Release (hr)				98.00								95.00	38.00
6) CsOH													
Total Release Fraction	7.70E-01	1.10E-02	6.10E-02	8.70E-02	2.70E-02	2.90E-01	5.00E-05	3.50E-04	4.50E-03	1.70E-01	3.10E-02	1.70E-02	2.90E-05
Total Plume 1 Release Fraction	7.00E-1	8.00E-3	3.40E-2	4.90E-2	2.60E-2	5.00E-4	2.60E-5	1.00E-5	7.00E-6	7.00E-5	3.10E-2	8.00E-3	2.60E-5
Start of Plume 1 Release (hr)	7.00	6.00	5.00	87.00	24.00	3.50	12.50	3.40	6.00	3.50	3.50	85.00	12.40
End of Plume 1 Release (hr)	8.00	11.00	8.00	89.00	25.00	4.50	17.00	13.00	9.00	13.50	4.00	87.00	18.00
Total Plume 2 Release Fraction	2.00E-2	1.00E-4	1.20E-2	3.00E-3	1.00E-3	7.00E-2	2.00E-6	2.00E-5	2.20E-3	2.20E-2	0.00E+0	0.00E+0	2.00E-6
Start of Plume 2 Release (hr)	8.00	11.00	8.00	89.00	25.00	17.00	17.00	13.00	60.75	36.50			18.00
End of Plume 2 Release (hr)	12.00	21.00	13.00	93.00	35.00	27.00	27.00	23.00	70.75	46.50			28.00

Table F.2-7
Braidwood Source Term Summary

	Release Category												
	LERF-ISLOCA	**LERF-CI**	**LERF-CFE**	**LERF-SGTR-AFW(1)**	**LERF-SGTR-NOAFW**	**LERF-ISGTR**	**LATE-BMT-AFW(2)**	**LATE-BMT-NOAFW**	**LATE-CHR-AFW(3)**	**LATE-CHR-NOAFW(4)**	**SERF-SGTR-TISGTR-HLF**	**SERF-SGTR-AFW-SC(5)**	**INTACT**
MAAP Case	1a	2a	3a	4a	5a	6a	7a	8a	9a	10a	11a	12b	13a
Run Duration	72 hr	72 hr	72 hr	200 hr	200 hr	800 hr	144 hr	144 hr	200 hrs	1600 hrs	72 hrs	200 hrs	72 hrs
Time after Scram when GE is declared	6.91	5.93	3.16	87.00	0.50	3.16	12.17	3.14	5.93	3.14	3.17	84.60	12.17
Fission Product Group:													
Total Plume 3 Release Fraction	5.00E-2	2.90E-3	1.50E-2	3.50E-2	0.00E+0	2.20E-1	2.20E-5	3.20E-4	2.30E-3	1.48E-1	0.00E+0	9.00E-3	1.00E-6
Start of Plume 3 Release (hr)	12.00	30.00	19.00	93.00		90.00	90.00	90.00	90.00	90.00		93.00	28.00
End of Plume 3 Release (hr)	22.00	40.00	29.00	98.00		100.00	100.00	95.00	100.00	100.00		95.00	38.00
7) BaO													
Total Release Fraction	1.20E-01	5.50E-04	1.10E-02	3.70E-02	2.30E-03	5.70E-04	3.00E-06	4.30E-06	1.40E-05	1.40E-04	3.10E-03	2.80E-03	1.50E-06
Total Plume 1 Release Fraction	1.20E-1	4.70E-4	1.10E-2	7.00E-3	2.00E-3	6.00E-5	2.10E-6	3.80E-6	9.00E-8	1.00E-5	3.10E-3	1.10E-3	1.40E-6
Start of Plume 1 Release (hr)	7.00	6.00	5.00	87.00	24.00	3.50	12.50	3.40	6.00	3.50	3.50	85.00	12.40
End of Plume 1 Release (hr)	8.00	11.00	8.00	89.00	25.00	4.50	17.00	13.00	9.00	13.50	4.00	87.00	18.00
Total Plume 2 Release Fraction	0.00E+0	6.00E-5	0.00E+0	6.00E-3	3.00E-4	5.00E-4	7.00E-7	0.00E+0	1.00E-7	2.00E-5	0.00E+0	5.00E-4	1.00E-7
Start of Plume 2 Release (hr)		11.00		89.00	25.00	17.00	17.00		60.75	36.50		87.00	18.00
End of Plume 2 Release (hr)		21.00		93.00	35.00	27.00	27.00		70.75	46.50		93.00	28.00
Total Plume 3 Release Fraction	0.00E+0	2.00E-5	0.00E+0	2.40E-2	0.00E+0	1.00E-5	2.00E-7	5.00E-7	1.40E-5	1.10E-4	0.00E+0	1.20E-3	0.00E+0

Table F.2-7
Braidwood Source Term Summary

	Release Category												
	LERF-ISLOCA	**LERF-CI**	**LERF-CFE**	**LERF-SGTR-AFW(1)**	**LERF-SGTR-NOAFW**	**LERF-ISGTR**	**LATE-BMT-AFW(2)**	**LATE-BMT-NOAFW**	**LATE-CHR-AFW(3)**	**LATE-CHR-NOAFW(4)**	**SERF-SGTR-TISGTR-HLF**	**SERF-SGTR-AFW-SC(5)**	**INTACT**
MAAP Case	1a	2a	3a	4a	5a	6a	7a	8a	9a	10a	11a	12b	13a
Run Duration	72 hr	72 hr	72 hr	200 hr	200 hr	800 hr	144 hr	144 hr	200 hrs	1600 hrs	72 hrs	200 hrs	72 hrs
Time after Scram when GE is declared	6.91	5.93	3.16	87.00	0.50	3.16	12.17	3.14	5.93	3.14	3.17	84.60	12.17
Fission Product Group:													
Start of Plume 3 Release (hr)		30.00		93.00		90.00	90.00	90.00	90.00	90.00		93.00	
End of Plume 3 Release (hr)		40.00		98.00		100.00	100.00	95.00	100.00	100.00		95.00	
8) La2O3													
Total Release Fraction	3.60E-03	1.90E-04	4.20E-04	4.50E-04	1.10E-05	8.00E-05	4.90E-07	4.00E-07	1.30E-06	7.30E-06	7.40E-06	4.10E-05	2.00E-08
Total Plume 1 Release Fraction	1.60E-3	1.60E-4	3.70E-4	2.00E-5	7.00E-6	3.00E-7	1.40E-7	2.50E-7	1.00E-9	1.00E-7	7.30E-6	3.00E-6	1.80E-8
Start of Plume 1 Release (hr)	7.00	6.00	5.00	87.00	24.00	3.50	12.50	3.40	6.00	3.50	3.50	85.00	12.40
End of Plume 1 Release (hr)	8.00	11.00	8.00	89.00	25.00	4.50	17.00	13.00	9.00	13.50	4.00	87.00	18.00
Total Plume 2 Release Fraction	1.90E-3	3.00E-5	1.00E-5	1.00E-5	4.00E-6	8.00E-5	3.40E-7	2.00E-8	1.00E-9	1.00E-7	1.00E-7	4.00E-6	2.00E-9
Start of Plume 2 Release (hr)	8.00	11.00	8.00	89.00	25.00	17.00	17.00	13.00	60.75	36.50	4.00	87.00	18.00
End of Plume 2 Release (hr)	12.00	21.00	13.00	93.00	35.00	27.00	27.00	23.00	70.75	46.50	14.00	93.00	28.00
Total Plume 3 Release Fraction	1.00E-4	0.00E+0	4.00E-5	4.20E-4	0.00E+0	0.00E+0	1.00E-8	1.30E-7	1.30E-6	7.10E-6	0.00E+0	3.40E-5	0.00E+0
Start of Plume 3 Release (hr)	12.00		19.00	93.00			90.00	90.00	90.00	90.00		93.00	
End of Plume 3 Release (hr)	22.00		29.00	98.00			100.00	95.00	100.00	100.00		95.00	

Table F.2-7
Braidwood Source Term Summary

	Release Category												
	LERF-ISLOCA	**LERF-CI**	**LERF-CFE**	**LERF-SGTR-AFW(1)**	**LERF-SGTR-NOAFW**	**LERF-ISGTR**	**LATE-BMT-AFW(2)**	**LATE-BMT-NOAFW**	**LATE-CHR-AFW(3)**	**LATE-CHR-NOAFW(4)**	**SERF-SGTR-TISGTR-HLF**	**SERF-SGTR-AFW-SC(5)**	**INTACT**
MAAP Case	1a	2a	3a	4a	5a	6a	7a	8a	9a	10a	11a	12b	13a
Run Duration	72 hr	72 hr	72 hr	200 hr	200 hr	800 hr	144 hr	144 hr	200 hrs	1600 hrs	72 hrs	200 hrs	72 hrs
Time after Scram when GE is declared	6.91	5.93	3.16	87.00	0.50	3.16	12.17	3.14	5.93	3.14	3.17	84.60	12.17
Fission Product Group:													
9) CeO2													
Total Release Fraction	4.20E-02	3.30E-04	2.10E-03	3.10E-03	2.10E-05	1.80E-03	8.00E-06	7.40E-06	6.00E-05	3.20E-04	1.10E-05	2.50E-04	1.80E-07
Total Plume 1 Release Fraction	1.30E-2	1.80E-4	1.10E-3	2.00E-4	1.40E-5	1.00E-6	2.10E-6	4.60E-6	4.00E-9	1.00E-7	1.10E-5	2.00E-5	1.60E-7
Start of Plume 1 Release (hr)	7.00	6.00	5.00	87.00	24.00	3.50	12.50	3.40	6.00	3.50	3.50	85.00	12.40
End of Plume 1 Release (hr)	8.00	11.00	8.00	89.00	25.00	4.50	17.00	13.00	9.00	13.50	4.00	87.00	18.00
Total Plume 2 Release Fraction	2.90E-2	4.00E-5	0.00E+0	1.00E-4	7.00E-6	1.80E-3	5.70E-6	5.00E-7	2.00E-9	2.00E-7	0.00E+0	2.00E-5	2.00E-8
Start of Plume 2 Release (hr)	8.00	11.00		89.00	25.00	17.00	17.00	13.00	60.75	36.50		87.00	18.00
End of Plume 2 Release (hr)	12.00	21.00		93.00	35.00	27.00	27.00	23.00	70.75	46.50		93.00	28.00
Total Plume 3 Release Fraction	0.00E+0	1.10E-4	1.00E-3	2.80E-3	0.00E+0	0.00E+0	2.00E-7	2.30E-6	6.00E-5	3.20E-4	0.00E+0	2.10E-4	0.00E+0
Start of Plume 3 Release (hr)		30.00	19.00	93.00			90.00	90.00	90.00	90.00		93.00	
End of Plume 3 Release (hr)		40.00	29.00	98.00			100.00	95.00	100.00	100.00		95.00	
10) Sb (Grouped with TeO2)													
Total Release Fraction	5.70E-01	3.10E-02	2.90E-01	6.10E-02	2.40E-02	2.50E-01	3.20E-03	2.10E-04	1.90E-02	2.00E-01	1.50E-02	8.00E-03	2.00E-05

Table F.2-7
Braidwood Source Term Summary

	Release Category												
	LERF-ISLOCA	**LERF-CI**	**LERF-CFE**	**LERF-SGTR-AFW(1)**	**LERF-SGTR-NOAFW**	**LERF-ISGTR**	**LATE-BMT-AFW(2)**	**LATE-BMT-NOAFW**	**LATE-CHR-AFW(3)**	**LATE-CHR-NOAFW(4)**	**SERF-SGTR-TISGTR-HLF**	**SERF-SGTR-AFW-SC(5)**	**INTACT**
MAAP Case	1a	2a	3a	4a	5a	6a	7a	8a	9a	10a	11a	12b	13a
Run Duration	72 hr	72 hr	72 hr	200 hr	200 hr	800 hr	144 hr	144 hr	200 hrs	1600 hrs	72 hrs	200 hrs	72 hrs
Time after Scram when GE is declared	6.91	5.93	3.16	87.00	0.50	3.16	12.17	3.14	5.93	3.14	3.17	84.60	12.17
Fission Product Group:													
Total Plume 1 Release Fraction	4.60E-01	4.00E-03	1.80E-01	3.10E-02	1.70E-02	2.00E-04	2.00E-05	4.00E-05	8.00E-06	1.00E-04	1.50E-02	4.40E-03	1.40E-05
Start of Plume 1 Release (hr)	7.00	6.00	5.00	87.00	24.00	3.50	12.50	3.40	6.00	3.50	3.50	85.00	12.40
End of Plume 1 Release (hr)	8.00	11.00	8.00	89.00	25.00	4.50	17.00	13.00	9.00	13.50	4.00	87.00	18.00
Total Plume 2 Release Fraction	4.00E-02	0.00E+00	2.00E-02	5.00E-03	5.00E-03	5.00E-02	1.00E-05	1.00E-05	6.00E-03	3.00E-02	0.00E+00	4.00E-04	3.00E-06
Start of Plume 2 Release (hr)	8.00		8.00	89.00	25.00	17.00	17.00	13.00	60.75	36.50		87.00	18.00
End of Plume 2 Release (hr)	12.00		13.00	93.00	35.00	27.00	27.00	23.00	70.75	46.50		93.00	28.00
Total Plume 3 Release Fraction	7.00E-02	2.70E-02	9.00E-02	2.50E-02	2.00E-03	2.00E-01	3.17E-03	1.60E-04	1.30E-02	1.70E-01	0.00E+00	3.20E-03	3.00E-06
Start of Plume 3 Release (hr)	12.00	30.00	19.00	93.00	35.00	90.00	90.00	90.00	90.00	90.00		93.00	28.00
End of Plume 3 Release (hr)	22.00	40.00	29.00	98.00	45.00	100.00	100.00	95.00	100.00	100.00		95.00	38.00
11) Te2 (Grouped with TeO2)													
Total Release Fraction	2.00E-04	2.00E-06	8.00E-05	0.00E+00	1.40E-11	0.00E+00	8.80E-07	9.50E-09	2.50E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total Plume 1 Release Fraction	0.00E+00	9.00E-07	1.00E-06	0.00E+00	0.00E+00	0.00E+00	3.00E-08	2.00E-11	2.00E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table F.2-7
Braidwood Source Term Summary

	Release Category												
	LERF-ISLOCA	**LERF-CI**	**LERF-CFE**	**LERF-SGTR-AFW(1)**	**LERF-SGTR-NOAFW**	**LERF-ISGTR**	**LATE-BMT-AFW(2)**	**LATE-BMT-NOAFW**	**LATE-CHR-AFW(3)**	**LATE-CHR-NOAFW(4)**	**SERF-SGTR-TISGTR-HLF**	**SERF-SGTR-AFW-SC(5)**	**INTACT**
MAAP Case	1a	2a	3a	4a	5a	6a	7a	8a	9a	10a	11a	12b	13a
Run Duration	72 hr	72 hr	72 hr	200 hr	200 hr	800 hr	144 hr	144 hr	200 hrs	1600 hrs	72 hrs	200 hrs	72 hrs
Time after Scram when GE is declared	6.91	5.93	3.16	87.00	0.50	3.16	12.17	3.14	5.93	3.14	3.17	84.60	12.17
Fission Product Group:													
Start of Plume 1 Release (hr)	7.00	6.00	5.00	87.00	24.00	3.50	12.50	3.40	6.00	3.50	3.50	85.00	12.40
End of Plume 1 Release (hr)	8.00	11.00	8.00	89.00	25.00	4.50	17.00	13.00	9.00	13.50	4.00	87.00	18.00
Total Plume 2 Release Fraction	1.90E-04	8.00E-07	7.00E-06	0.00E+00	5.00E-12	0.00E+00	1.00E-08	1.00E-11	7.00E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Start of Plume 2 Release (hr)	8.00	11.00	8.00		25.00		17.00	13.00	60.75				
End of Plume 2 Release (hr)	12.00	21.00	13.00		35.00		27.00	23.00	70.75				
Total Plume 3 Release Fraction	1.00E-05	3.00E-07	7.20E-05	0.00E+00	9.00E-12	0.00E+00	8.40E-07	9.47E-09	1.80E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Start of Plume 3 Release (hr)	12.00	30.00	19.00		35.00		90.00	90.00	90.00				
End of Plume 3 Release (hr)	22.00	40.00	29.00		45.00		100.00	95.00	100.00				
12) UO2 (Grouped with CeO2)													
Total Release Fraction	2.40E-04	8.70E-07	2.20E-05	0.00E+00	2.20E-14	2.50E-05	7.30E-08	1.50E-07	2.20E-07	4.10E-06	0.00E+00	0.00E+00	0.00E+00
Total Plume 1 Release Fraction	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.00E-09	4.00E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Start of Plume 1 Release (hr)			5.00	87.00	24.00	3.50	12.50	3.40	6.00	3.50	3.50	85.00	12.40
End of Plume 1 Release (hr)			8.00	89.00	25.00	4.50	17.00	13.00	9.00	13.50	4.00	87.00	18.00

Table F.2-7
Braidwood Source Term Summary

	Release Category												
	LERF-ISLOCA	**LERF-CI**	**LERF-CFE**	**LERF-SGTR-AFW(1)**	**LERF-SGTR-NOAFW**	**LERF-ISGTR**	**LATE-BMT-AFW(2)**	**LATE-BMT-NOAFW**	**LATE-CHR-AFW(3)**	**LATE-CHR-NOAFW(4)**	**SERF-SGTR-TISGTR-HLF**	**SERF-SGTR-AFW-SC(5)**	**INTACT**
MAAP Case	1a	2a	3a	4a	5a	6a	7a	8a	9a	10a	11a	12b	13a
Run Duration	72 hr	72 hr	72 hr	200 hr	200 hr	800 hr	144 hr	144 hr	200 hrs	1600 hrs	72 hrs	200 hrs	72 hrs
Time after Scram when GE is declared	6.91	5.93	3.16	87.00	0.50	3.16	12.17	3.14	5.93	3.14	3.17	84.60	12.17
Fission Product Group:													
Total Plume 2 Release Fraction	1.70E-04	3.00E-11	1.00E-07	0.00E+00	1.70E-14	2.50E-05	4.60E-08	1.00E-08	0.00E+00	1.00E-11	0.00E+00	0.00E+00	0.00E+00
Start of Plume 2 Release (hr)	8.00	11.00	8.00		25.00	17.00	17.00	13.00		36.50			
End of Plume 2 Release (hr)	12.00	21.00	13.00		35.00	27.00	27.00	23.00		46.50			
Total Plume 3 Release Fraction	7.00E-05	8.70E-07	2.19E-05	0.00E+00	5.00E-15	0.00E+00	1.80E-08	1.00E-07	2.20E-07	4.10E-06	0.00E+00	0.00E+00	0.00E+00
Start of Plume 3 Release (hr)	12.00	30.00	19.00		35.00		90.00	90.00	90.00	90.00			
End of Plume 3 Release (hr)	22.00	40.00	29.00		45.00		100.00	95.00	100.00	100.00			

(1) LERF-SGTR-AFW: All three plume start times and GE time were reduced by 50 hours to conform to MACCS2 input limits.
(2) LATE-BMT-AFW: Plume 3 start time reduced from 107 hours to 90 hours to conform to MACCS2 input limits.
(3) LATE-CHR-AFW: Plume 3 start time reduced from 120 hours to 90 hours to conform to MACCS2 input limits.
(4) LATE-CHR-NOAFW: Plume 3 start time reduced from 126 hours to 90 hours to conform to MACCS2 input limits.
(5) SERF-SGTR-AFW-SC: All three plume start times and GE time were reduced by 40 hours to conform to MACCS2 input limits.

Table F.2-8
Detailed Release Category Results

Endstate	BW Unit 1		BW Unit 2	
	Freq (/yr)	Percent	Freq (/yr)	Percent
INTACT	1.35E-05	35.5%	1.36E-05	36.5%
SERF-TISGTR-HLF	8.12E-09	0.0%	8.24E-09	0.0%
SERF-SGTR-AFW-SC	1.48E-06	3.9%	1.70E-06	4.6%
LATE-BMMT-AFW	6.07E-07	1.6%	5.89E-07	1.6%
LATE-BMMT-NOAFW	9.95E-08	0.3%	1.04E-07	0.3%
LATE-CHR-AFW	1.37E-05	36.1%	1.30E-05	34.8%
LATE-CHR-NOAFW	7.51E-06	19.8%	7.28E-06	19.5%
-LERF-ISLOCA	3.40E-07	0.9%	3.40E-07	0.9%
LERF-CI	3.63E-07	1.0%	3.51E-07	0.9%
LERF-CFE	3.14E-08	0.1%	3.06E-08	0.1%
LERF-SGTR-AFW	5.92E-08	0.2%	6.81E-08	0.2%
LERF-SGTR-NOAFW	9.64E-10	0.0%	9.64E-10	0.0%
LERF-ISGTR	2.57E-07	0.7%	2.51E-07	0.7%
Total	3.79E-05	100.0%	3.73E-05	100.0%

Table F.3-1
County Based Growth Rates 2000 - 2030

County	Growth Rate 2000 - 2030 Percentage
Indiana	
Jasper	27.3%
Lake	6.5%
Newton	0.0%(1)
Illinois	
Bureau	14.8%
Cook	11.2%
DeKalb	39.4%
DuPage	14.2%
Ford	12.2%
Grundy	34.1%
Iroquois	15.7%
Kane	67.8%
Kankakee	21.6%
Kendall	55.7%
La Salle	26.8%
Lee	7.8%
Livingston	13.6%
McLean	32.1%
Marshall	8.6%
Putnam	11.0%
Will	117.3%
Woodford	31.9%

(1) Calculated growth rate was -9.1%. Zero growth is assumed.

Table F.3-2
Estimated Population Distribution within a 10-Mile Radius of Braidwood, Year 2047

Sector	0-1 mile	1-2 miles	2-3 miles	3-4 miles	4-5 miles	5-10 miles	10-mile Total(1)
N	260	3237	2300	25	767	7583	14172
NNE	712	5949	3324	1332	12557	3028	26902
NE	0	5862	5551	1342	206	30917	43878
ENE	43	256	18	531	509	5446	6803
E	22	55	250	170	904	46442	47843
ESE	0	0	633	68	62	1259	2022
SE	0	0	40	4244	175	467	4926
SSE	0	0	0	6505	567	1289	8361
S	0	0	0	5	3414	972	4391
SSW	0	0	37	12	71	2674	2794
SW	1332	909	336	4051	57	3270	9955
WSW	608	201	1095	42	543	916	3405
W	33	21	105	20	51	573	803
WNW	0	16	32	111	295	469	923
NW	221	7	131	2261	5340	7322	15282
NNW	0	2625	570	3262	441	5775	12673
Total(1)	3231	19138	14422	23981	25959	118402	205133

(1) Population projections developed in electronic spreadsheet calculation and totals may differ slightly due to rounding of individual values.

Table F.3-3
Estimated Population Distribution within a 50-Mile Radius of Braidwood, Year 2047

Sector	0-10 miles	10-20 miles	20-30 miles	30-40 miles	40-50 miles	50-mile Total(1)
N	14172	75945	203591	724663	540416	1558787
NNE	26902	73317	525571	445618	1086352	2157760
NE	43878	20570	274470	473546	1477624	2290088
ENE	6803	4682	38409	359548	399178	808620
E	47843	6197	13568	13520	25487	106615
ESE	2022	38842	58975	7618	3142	110599
SE	4926	2219	6419	3215	11842	28621
SSE	8361	3107	1754	6962	3638	23822
S	4391	1013	1637	3672	3098	13811
SSW	2794	761	1289	8285	2143	15272
SW	9955	7658	2003	18023	8665	46304
WSW	3405	817	1792	26888	7772	40674
W	803	3182	2043	14303	42009	62340
WNW	923	3246	14112	25540	6903	50724
NW	15282	23976	7273	31894	8339	86764
NNW	12673	4237	20510	78166	38611	154197
Total(1)	205133	269769	1173416	2241461	3665219	7554998

1 Population projections developed in electronic spreadsheet calculation and totals may differ slightly due to rounding of individual values.

Table F.3-4
County Specific Land Use and Economic Parameters Inputs

County	Fraction Farm	Fraction Dairy	Farm Sales ($/hectare)	Farm Property Value ($/hectare)	Non-Farm Property Value ($/person)
Illinois					
Bureau	0.860	0.002	1,566	11,058	225,984
Cook	0.014	0.036	4,601	28,166	318,318
DeKalb	0.918	0.013	2,013	12,637	203,355
DuPage	0.038	0.000	4,374	20,475	377,720
Ford	0.871	0.002	1,331	10,842	245,302
Grundy	0.805	0.003	1,206	11,333	221,907
Iroquois	0.948	0.006	1,525	11,001	219,678
Kane	0.578	0.018	2,544	13,291	246,480
Kankakee	0.891	0.008	1,562	11,821	205,441
Kendall	0.814	0.008	1,532	11,800	223,356
LaSalle	0.886	0.001	1,263	11,455	219,164
Lee	0.852	0.002	1,338	11,761	206,626
Livingston	0.941	0.009	1,378	11,316	242,240
McLean	0.893	0.053	1,339	11,409	249,616
Marshall	0.828	0.005	1,215	11,045	236,754
Putnam	0.613	0.008	2,557	10,760	241,773
Will	0.412	0.013	1,427	15,381	255,570
Woodford	0.854	0.005	1,521	11,584	254,629
Indiana					
Jasper	0.950	0.340	2,130	9,123	218,608
Lake	0.404	0.065	1,195	10,822	224,135
Newton	0.741	0.003	2,508	9,848	195,342

Table F.3-5
Braidwood MACCS2 Generic Economic Parameters

Variable	Description	Value
DPRATE[(1)]	Property depreciation rate (per yr)	0.20
DSRATE[(2)]	Investment rate of return (per yr)	0.07
EVACST[(3)]	Daily cost for a person who has been evacuated ($/person-day)	56.43
RELCST[(3)]	Daily cost for a person who is relocated ($/person-day)	56.43
POPCST[(3)]	Population relocation cost ($/person)	10,450
CDFRM0[(3)]	Cost of farm decontamination for two levels of decontamination ($/hectare)[(5)]	1,176 2,613
CDNFRM[(3)]	Cost of non-farm decontamination per resident person for various levels of decontamination ($/person)[(5)]	6,270 16,720
TIMDEC[(1)]	Decontamination time for each level[(5)]	2 & 4 months
DLBCST[(3)]	Average cost of decontamination labor ($/man-year)	73,150
TFWKF[(1)]	Time decontamination workers spend in farm land contaminated areas[(5)]	1/10 1/3
TWWNF[(1)]	Time decontamination workers spend in non-farm land contaminated areas[(5)]	1/3 1/3
VALWF0[(4)]	Value of farm wealth ($/hectare)	11,680
VALWNF[(4)]	Value of non-farm wealth ($/person)	297,748

(1) DPRATE uses NUREG/CR-4551 value (NRC 1990b).

(2) DSRATE based on NUREG/BR-0058 (NRC 2004a).

(3) These parameters use the NUREG/CR-4551 values (NRC 1990b), updated to July 2012 using the consumer price index.

(4) VALWF0 and VALWNF are based on 2007 National Agriculture Census (USDA 2009) and Bureau of Economic Analysis 2007 data (BEA 2012), updated to the July 2012 using the consumer price index.

(5) Two decontamination levels are modeled, consistent with NUREG/CR-4551 (NRC 1990b). The first value is associated with a dose reduction factor of 3. The second value is associated with a dose reduction factor of 15.

Table F.3-6
Braidwood MACCS2 End of Cycle Core Inventory

Entry	Nuclide	Activity (Bq)	Entry	Nuclide	Activity (Bq)
1	Co-58	3.39E+16	31	Te-131m	5.09E+17
2	Co-60	2.59E+16	32	Te-132	5.05E+18
3	Kr-85	3.79E+16	33	I-131	3.55E+18
4	Kr-85m	1.14E+18	34	I-132	5.13E+18
5	Kr-87	2.25E+18	35	I-133	7.34E+18
6	Kr-88	3.18E+18	36	I-134	8.15E+18
7	Rb-86	8.60E+15	37	I-135	6.85E+18
8	Sr-89	3.86E+18	38	Xe-133	7.16E+18
9	Sr-90	2.98E+17	39	Xe-135	2.03E+18
10	Sr-91	5.22E+18	40	Cs-134	7.04E+17
11	Sr-92	5.49E+18	41	Cs-136	2.00E+17
12	Y-90	3.12E+17	42	Cs-137	4.08E+17
13	Y-91	4.72E+18	43	Ba-139	6.76E+18
14	Y-92	5.51E+18	44	Ba-140	6.53E+18
15	Y-93	6.14E+18	45	La-140	6.69E+18
16	Zr-95	6.05E+18	46	La-141	6.17E+18
17	Zr-97	6.19E+18	47	La-142	6.05E+18
18	Nb-95	6.10E+18	48	Ce-141	5.97E+18
19	Mo-99	6.72E+18	49	Ce-143	5.93E+18
20	Tc-99m	5.88E+18	50	Ce-144	4.53E+18
21	Ru-103	5.44E+18	51	Pr-143	5.78E+18
22	Ru-105	3.71E+18	52	Nd-147	2.44E+18
23	Ru-106	1.84E+18	53	Np-239	6.87E+19
24	Rh-105	3.39E+18	54	Pu-238	1.36E+16
25	Sb-127	3.78E+17	55	Pu-239	1.02E+15
26	Sb-129	1.13E+18	56	Pu-240	1.19E+15
27	Te-127	3.73E+17	57	Pu-241	4.71E+17

Table F.3-6
Braidwood MACCS2 End of Cycle Core Inventory

Entry	Nuclide	Activity (Bq)	Entry	Nuclide	Activity (Bq)
28	Te-127m	4.87E+16	58	Am-241	5.21E+14
29	Te-129	1.11E+18	59	Cm-242	1.47E+17
30	Te-129m	1.66E+17	60	Cm-244	1.61E+16

Table F.3-7
MACCS2 Release Categories vs. Braidwood Release Categories

MACCS2 Release Categories	Braidwood Release Categories
Xe/Kr	1 – noble gases
I	2 – CsI
Cs	6 & 2 – CsOH and CsI(3)
Te	3 & 11- TeO_2, Sb(2) & Te_2 (1)
Sr	4 – SrO
Ru	5 – MoO_2 (Mo is in Ru MACCS category)
La	8 – La_2O_3
Ce	9 – CeO_2 & UO_2 (1)
Ba	7 – BaO

(1) These release fractions are typically negligible compared to others in the group.

(2) The mass of Sb in the core is typically much less than the mass of Te.

(3) The mass of Cs contained in CsI is typically much less than the mass of Cs contained in CsOH.

Table F.3-8
Representative MAAP Level 2 Case Descriptions and Key Event Timings

Source Term	Release Category	MAAP Case	MAAP Case Justification and Description	CsI RF [(1)]	Tcd [(2)] (Hrs)	Tvf [(3)] (Hrs)	Tcf [(4)] (Hrs)	Tend [(5)] (Hrs)
ST1	LERF-ISLOCA	1a	Sequence Contributors: LERF11-ISLOCA (100%). The Level 1 1ILOC-03 sequence is the dominant contributor and is used to characterize the release category. This sequence is a break in the RHR discharge line outside containment followed by successful injection, but core damage ensues as there is no water in the sump for recirculation mode ILOC-04, the other top contributor, is similar, but the break is in the RHR suction line.. MAAP Case: ISLOCA in the RHR discharge line (800 gpm break), successful scram, successful injection, recirculation unavailable, core damage, containment bypass..	0.78	6.91	9.65	Bypass	72
ST2	LERF-CI	2a	Sequence Contributors: LERF09 (100%). There are many different contributions to this release category due to its inclusive nature, but a vast majority include failure of the recirculation mode after successful injection. Approximately 60% of the total contribution comes from small LOCA scenarios (both small LOCA initiators and RCP seal LOCAs that evolve from other initiating events). The remaining 40% is comprised mostly of loss of SX and Flooding events. Medium LOCAs are small contributors and are almost all recirculation failures. A truly representative sequence for this release category would be a small LOCA with recirculation failure, but to address the faster evolving contributors with injection failures, the seal LOCA with F&B failure is used MAAP Case: Loss of SX, successful scram, RCP seal LOCA, injection failure, core damage, containment isolation failure.	1.4E-2	5.93	8.67	ISLOCA	72

Table F.3-8
Representative MAAP Level 2 Case Descriptions and Key Event Timings

Source Term	Release Category	MAAP Case	MAAP Case Justification and Description	CsI RF (1)	Tcd (2) (Hrs)	Tvf (3) (Hrs)	Tcf (4) (Hrs)	Tend (5) (Hrs)
ST3	LERF-CFE	3a	Sequence Contributors: LERF02 (69%), LERF03 (26%). The main difference between sequences LERF02 and LERF03 with respect to equipment availability is that AFW is available for LERF02 while it is not for LERF03. Both sequences include a mixture of injection and recirculation failures. Because LERF03 scenarios may evolve more quickly, they are used as the representative sequence as injection failure cases. MAAP Case: Loss of SX, successful scram, no AFW, FW not restored, seal cooling successful, operator fail to initiate feed and bleed injection, core damage, successful operator action to depressurize the RCS prior to vessel failure or tube rupture, vessel melt, and containment failure due to hydrogen burn.	0.30	3.16	5.11	5.11	72
ST4	LERF-SGTR-AFW	4a	Sequence Contributors: LERF10 (100About 75% of the contributors are the result of operator failure to cool down the RCS in time to prevent passing water through the SG PORVs followed by operator failure to cool down the RCS to terminate SGTR break flow before RWST depletion. An additional 10% of the contribution is from failure to cool down the RCS in time to prevent passing water through the SG PORVs followed by operator failure to failure to throttle SX007 for recirculation (for BW). The consequences of these scenarios are similar and the larger contributor is chose as representative. MAAP Case: SGTR, successful scram, SG isolation successful, failure to cool down RCS before passing water through the SG PORV, stuck open SG PORV, RCS injection successful, failure to cool down the RCS before RWST depletion, core damage, release through tubes.	9.7E-2	137.0	155.19	NA	200

Table F.3-8
Representative MAAP Level 2 Case Descriptions and Key Event Timings

Source Term	Release Category	MAAP Case	MAAP Case Justification and Description	CsI RF (1)	Tcd (2) (Hrs)	Tvf (3) (Hrs)	Tcf (4) (Hrs)	Tend (5) (Hrs)
ST5	LERF-SGTR-NOAFW	5a	Sequence Contributors: LERF11(100%). The contributing scenarios are dominated by common cause failure of AFW followed by failure to restore MFW. MAAP Case: SGTR, scram successful, AFW fails, FW not restored, injection successful, RWST depletes, core damage, release through tubes.	4.1E-2	23.82	31.13	NA	200
ST6	LERF-ISGTR	6a	Sequence Contributors: LERF08 (99%), LERF07 (1%). Most of the induced tube rupture scenarios are pressure induced tube ruptures (LERF08), but thermally induced ruptures (LEFF07) are also represented in the cutsets. The TI-SGTR contribution to LERF is small relative to the PI-SGTR due to likelihood of hot leg failure near the time of TI-SGTR (eliminates release pathway). Both scenarios, however, are dominated by transient initiators with AFW unavailability, most of which lead to recirculation failures. Feed and Bleed failures are smaller contributors, but because of the potential impact on the source terms, the Feed and Bleed failure scenario is chosen as the representative case. MAAP Case: Loss of SW, successful scram, AFW unavailable, operators fail to align alt FW and fail to align F&B, core damage, pressure induced tube rupture occurs.	0.19	3.16	7.39	17.23	800

Table F.3-8
Representative MAAP Level 2 Case Descriptions and Key Event Timings

Source Term	Release Category	MAAP Case	MAAP Case Justification and Description	CsI RF (1)	Tcd (2) (Hrs)	Tvf (3) (Hrs)	Tcf (4) (Hrs)	Tend (5) (Hrs)
ST7	LATE-BMT-AFW	7a	Sequence Contributors: Late04 (81%), Late01 (13%). For both the LATE04 and LATE01 sequences, most of the contributors are LOCA events (including seal LOCAs) with recirculation failures. The availability of water on the containment floor impacts the probability of the basemat meltthrough, but has a negligible impact on the source term itself. For the basemat failure releases, the differences in LOCA size also have a minimal impact on the results. The largest frequency contributor is chosen as the representative sequence, which are the small LOCAs. MAAP Case: Small LOCA, successful scram, AFW available, injection successful, recirculation mode failure, core damage, containment heat removal success (RCFCs), CS success, basemat melt through.	6.8E-5	12.17	15.22	107.40	144
ST8	LATE-BMT-NOAFW	8a	Sequence Contributors: Late07 (89%), Late08 (11%). The difference in the two dominant Level 2 sequences is related to operation of Containment Spray, which determines if there is a water pool in the reactor cavity when the core relocates to the containment. The scenarios for both sequences are essentially the same, most being transients with AFW failure followed by a mixture of either injection or recirculation mode failures. For this case, the scenarios with the feed and bleed failures are chosen as representative to capture any potential timing issues for evacuation. MAAP Case: General transient event, successful scram, AFW CCF to run, failure to restore FW, failure to initiate feed and bleed, core damage, no PI-SGTR, op depressurizes late, no early containment failure at vessel breach, CHR successful, CS successful, basemat failure.	7.4E-4	3.14	6.88	90.10	144

Table F.3-8
Representative MAAP Level 2 Case Descriptions and Key Event Timings

Source Term	Release Category	MAAP Case	MAAP Case Justification and Description	CsI RF (1)	Tcd (2) (Hrs)	Tvf (3) (Hrs)	Tcf (4) (Hrs)	Tend (5) (Hrs)
ST9	LATE-CHR-AFW	9a	Sequence Contributors: Late06 accounts for almost all of the contributions to this release category frequency. Over 92% of the contribution to the release category is from LOSW events or events that lead to SX failure, followed by a seal LOCA. The other contributions are almost all scenarios that result in a seal LOCA in a different manner. Recirculation and injection failures are both represented, but most are injection failures. MAAP Case: LOSW, successful scram, AFW failed, normal FW OK, failure to align alternate seal cooling, failure to align SX X-tie, seal LOCA, injection failure, core damage, no containment failure at VB, CHR fails with long term COP.	1.4E-2	5.93	8.88	60.78	200
ST10	LATE-CHR-NOAFW	10a	Sequence Contributors: Late09 accounts for almost all of the contributions to this release category frequency. Over 96% of the release category frequency is from LOSW events or events that lead to SX failure. These are generally followed by the unavailability of FW/Condensate and recirculation mode; injection failures contribute less than 10% of the frequency. MAAP Case: LOSW (all SX pumps CCF), successful scram, AFW failure from lack of SX cooling, failure to restore FW, SX X-tie not available, CHR not available for recirc, core damage, operator depressurizes late, no containment failure at VB, CHR fails with long term COP.	0.24	3.14	10.12	36.50	1600
ST11	SERF-SGTR - TISGTR-HLF	11a	Sequence Contributors: The SERF01 sequence is comprised of mostly feed and bleed failures with some recirculation failures after failure of AFW. The more rapidly evolving feed and bleed failures are chosen as the representative sequences. MAAP Case: Loss of 125 DC bus 111, successful scram, failure of AFW, failure of feed and bleed, core damage, late depressurization failure, TI-SGTR occurs, Hot leg fails at about the same time as TI-SGTR, no early containment failure, CHR success, CS success, no basemat failure.	5.8E-2	3.17	6.69	NA	72

Table F.3-8
Representative MAAP Level 2 Case Descriptions and Key Event Timings

Source Term	Release Category	MAAP Case	MAAP Case Justification and Description	CsI RF (1)	Tcd (2) (Hrs)	Tvf (3) (Hrs)	Tcf (4) (Hrs)	Tend (5) (Hrs)
ST12	SERF-SGTR-AFW-SC	12b	Sequence Contributors: The SERF02 sequence is mostly comprised (65% based on the Unit 2 results that correctly include 2RX-JHEP33-HOADA) of SGTR events with failure the operators to cool down the RCS before overfilling the SG (opens a steam generator PORV for a LOCA) and subsequent operator error to cool down the RCS to terminate the break flow before depleting the RWST. An additional 8% of the contribution is related to operator failure to throttle the 0SX007 valve during transition to recirculation after a successful break termination (for BW). The cases including 2RX-JHEP33-HOADA (about 8%) are SGTR events with operator failures to shut down dead headed RHR pumps (fails RH) and failure to reduce ECCS injection (to prevent lifting the SG safety valves). MAAP Case: SGTR, successful scram, operator fails to cool down the RCS, SG overfill causes stuck open PORV, operator fails to cool down the RCS to terminate break flow before the RWST is depleted, recirculation mode is unavailable, core damage, operators maintain SG level over the top of the SG tubes for release scrubbing.	1.8E-2	124.6	142.79	NA	200
ST13	INTACT	13a	Sequence Contributors: Most of the intact contribution comes from small LOCA scenarios (including induced Small LOCAs) with recirculation failures. For intact containment scenarios, the path to core damage has a negligible impact on the source term. MAAP case: Small LOCA, successful scram, AFW available, injection successful, recirculation failure, core damage, containment intact.	3.2E-5	12.17	15.13	NA	72

Table F.3-9
MACCS2 Base Case Mean Results Unit 1

Source Term	Release Category	Dose (p-rem)	Offsite Economic Cost ($)	Freq. (/yr)	Dose-Risk (p-rem/yr)	OECR ($/yr)
ST1	LERF-ISLOCA	4.57E+07	**1.60E+11**	3.40E-07	1.55E+01	5.44E+04
ST2	LERF-CI	3.25E+06	**1.04E+10**	3.63E-07	1.18E+00	3.78E+03
ST3	LERF-CFE	9.31E+06	**6.38E+10**	3.14E-08	2.92E-01	2.00E+03
ST4	LERF-SGTR-AFW	8.76E+06	**7.47E+10**	5.92E-08	5.19E-01	4.42E+03
ST5	LERF-SGTR-NOAFW	3.09E+06	**2.44E+10**	9.64E-10	2.98E-03	2.35E+01
ST6	LERF-ISGTR	1.09E+07	**1.26E+11**	2.57E-07	2.80E+00	3.24E+04
ST7	LATE-BMT-AFW	6.64E+04	**5.08E+07**	6.07E-07	4.03E-02	3.08E+01
ST8	LATE-BMT-NOAFW	1.91E+05	**3.10E+08**	9.95E-08	1.90E-02	3.08E+01
ST9	LATE-CHR-AFW	1.56E+06	**3.30E+09**	1.37E-05	2.14E+01	4.52E+04
ST10	LATE-CHR-NOAFW	8.78E+06	**8.55E+10**	7.51E-06	6.59E+01	6.42E+05
ST11	SERF-SGTR-TISGTR-HLF	3.71E+06	**2.82E+10**	8.12E-09	3.01E-02	2.29E+02
ST12	SERF-SGTR-AFW-SC	3.85E+06	**1.67E+10**	1.48E-06	5.70E+00	2.47E+04
ST13	INTACT	2.48E+04	**2.24E+07**	1.34E-05	3.32E-01	3.00E+02
FREQUENCY WEIGHTED TOTALS				3.79E-05	1.14E+02	8.10E+05

Table F.5-1
Braidwood Level 1 IE Importance List Review

Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
%SXIE	9.60E-01	1.56	INDICATOR FOR SX INITIATING EVENT	SX impacts several critical functions and systems and multiple SAMAs are potentially relevant. For failure of all SX pumps (both units) to run (a majority contributor), most contributors include operator failures such that additional actions would provide limited benefit. A diesel driven SX pump with suction from the WS forebay with an auto start function could be used to mitigate CCF failures of the SX pumps. To maximize benefit, backup manual controls would have to be included in the MCR (SAMA 1). For cases in which aligning alternate cooling to the charging pump fails, the PDP could be replaced with a self-cooled high pressure injection pump with the capability to auto start on loss of charging flow (SAMA 2). For the contributors in which the failure of SX is due to the failure to start the standby SX pump, automating the start of the standby SX pump on failure of the running pump is a potential solution (SAMA 3). Instead of replacing the PDP to protect the RCP seals, a passive means of preventing a seal LOCA would be to install "no leak" RCP seals (SAMA 4). Another potential means of mitigating this scenario would be to modify the Startup FW pump to auto start and align on low SG level (using the AMSAC SG level signal) (SAMA 5).

Table F.5-1
Braidwood Level 1 IE Importance List Review

Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
FLAG-CCHTX0-U2	5.00E-01	1.264	CCW HTX 0 ALIGNED TO UNIT 2	This event is a plant configuration flag that represents conditions when the 0HX is aligned to the non-accident unit. Over 55% of the contributors including this flag are related to the operator actions linked with preventing seal LOCAs, such as starting the standby SW/CCW pump, providing alternate cooling to the charging pumps, performing the SX cross-tie. Loss of SX evolutions leading to seal LOCAs can be addressed by replacing the PDP with a self-cooled high pressure injection pump with the capability to auto start on loss of charging flow (SAMA 2). An alternate means of preventing a seal LOCA would be to install "no leak" RCP seals (SAMA 4). Automating the start of the standby SX pump would also reduce some of these contributors and may be viable if combined with flooding sensors that would prevent auto start in flooding scenarios (SAMA 3). In addition, failure to throttle the _SX007 valve is a significant contributor. While it is not unreasonable to expect the RHR/CC temperatures would be closely monitored in the MCR, updating the procedures to explicitly direct an independent check of the valve throttling action would improve the assessed reliability of the action (SAMA 6). Fire protection system flooding in the Aux Building is another contributor, which could be mitigated by installing fire protection pump controls in the MCR (SAMA 8) or by installing flow restrictors in the fire protection lines (SAMA 9).

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Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
0SX01AB2AB-CPMFRIE	2.16E-04	1.244	FAILURE OF ALL SX PUMPS (1A/1B/2A/2B) TO RUN DUE TO CCF (4/4)	These events represent a loss of all SX due to common cause pump failure. A diesel driven SX pump could be used to mitigate CCF failures of the SX pumps. To maximize benefit, controls would have to be included in the MCR (SAMA 1). For cases in which no seal LOCA occurs, secondary side heat removal can prevent core damage. The top contributor including SX pump CCF is the failure to recover FW for heat removal (about 40%). A potential means of mitigating this scenario would be to modify the Startup FW pump to auto start and align on low SG level (using the AMSAC SG level signal) (SAMA 5). For cases with seal LOCAS, the PDP could be replaced with a self-cooled high pressure injection pump with the capability to auto start on loss of charging flow (SAMA 2). An alternate means of preventing a seal LOCA would be to install "no leak" RCP seals (SAMA 4).

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Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
0SX007-ES13HMVOA	3.40E-03	1.225	OPERATORS FAIL TO LOCALLY THROTTLE SX007 TO CC HXS	This action is required at Braidwood because the _SX007 valves are not maintained in their accident position and a local operation is required when they are needed in an accident scenario. While the action is reliable, review of the HRA indicates that the dominant contributor is the execution component. Currently, the procedures do not explicitly direct the operators to independently check the throttling action, which results in a relatively large failure probability for a simple execution. While it is not unreasonable to expect the RHR/CC temperatures would be closely monitored in the MCR, updating the procedures to explicitly direct an independent check of the valve throttling action would improve the assessed reliability of the action (SAMA 6).

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Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
FLAG-CCHTX0-U1	5.00E-01	1.217	CCW HTX 0 ALIGNED TO UNIT 1	This event is a plant configuration flag that represents conditions when the 0HX is aligned to the accident unit. Over 50% of the contributors including this flag are related to the operator actions linked with preventing seal LOCAs, such as starting the standby SW/CCW pump, providing alternate cooling to the charging pumps, performing the SX cross-tie. Loss of SX evolutions leading to seal LOCAs can be addressed by replacing the PDP with a self-cooled high pressure injection pump with the capability to auto start on loss of charging flow (SAMA 2). An alternate means of preventing a seal LOCA would be to install "no leak" RCP seals (SAMA 4). Automating the start of the standby SX pump would also reduce some of these contributors and may be viable if combined with flooding sensors that would prevent auto start in flooding scenarios (SAMA 3). In addition, failure to throttle the _SX007 valve is a significant contributor. While it is not unreasonable to expect the RHR/CC temperatures would be closely monitored in the MCR, updating the procedures to explicitly direct an independent check of the valve throttling action would improve the assessed reliability of the action (SAMA 6). Fire protection system flooding in the Aux Building is another contributor, which could be mitigated by installing fire protection pump controls in the MCR (SAMA 8) or by installing flow restrictors in the fire protection lines (SAMA 9).

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Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
%RC-SLOC1-N-PSIE	1.40E-03	1.212	SMALL LOCA INITIATING EVENT (NON-ISOLABLE)	Over 75% of the contribution from the small LOCA initiating event is related to the failure to throttle _SX007 valves. While it is not unreasonable to expect the RHR/CC temperatures would be closely monitored in the MCR, updating the procedures to explicitly direct an independent check of the valve throttling action would improve the assessed reliability of the action (SAMA 6). About 16% of the contribution is related to the failure to stop the RH pumps when they are on min-flow without CC cooling to the RH heat exchangers. A potential enhancement may be to establish CC to the RH heat exchanger when the RH pumps start (SAMA 7).

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Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
1RX-JHEP05-HOADA	3.30E-04	1.189	JHEP - 1RC-PUMPS--HPMOA/0SX-XTIE---HMVOA/(1FP-PRI-7X-HMVOA OR 1CV-ALL----HPMOA)	This JHEP represents the failure of 4 different actions: starting the standby CCW/CCP/SX pump (it is the SX pump for these contributors), aligning the inter-unit SX cross-tie, aligning fire protection water to charging pump lube oil cooling, and establishing a cool suction source for the charging pumps. For cases in which aligning alternate cooling to the charging pump fails, the PDP could be replaced with a self-cooled high pressure injection pump with the capability to auto start on loss of charging flow (SAMA 2). Automating the start of the standby SX pump would also reduce these contributors and may be viable if combined with flooding sensors that would prevent auto start in flooding scenarios (SAMA 3). Automating the SX X-tie is not suggested given that certain failures in the SX system could fail the non-accident unit if the X-tie is performed without consideration of the failure scenario. Installation of "no leak" RCP seals is another option (SAMA 4).

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Braidwood Level 1 IE Importance List Review

Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
0SX-XTIE-D-HMVRA	3.50E-01	1.164	RECOV OF LOSS OF SX SEAL LOCA (COND PROB OF 0SX-XTIE-D-HMVRA + 0.21 SEAL FAIL)	This is a composite event that represents the probability that either the seal LOCA is too large for the CVCS to mitigate, or that the SX cross-tie is not performed in time to support injection with CVCS (to prevent core damage). Main contributors include dependent operator action groups that include failures related to aligning alternate charging pump cooling, starting the standby SX pumps, and aligning the SX X-tie to prevent the seal LOCA. For cases in which aligning alternate cooling to the charging pump fails, the PDP could be replaced with a self-cooled high pressure injection pump with the capability to auto start on loss of charging flow (SAMA 2). Automating the start of the standby SX pump would also reduce these contributors and may be viable if combined with flooding sensors that would prevent auto start in flooding scenarios (SAMA 3). An alternate means of preventing a seal LOCA would be to install "no leak" RCP seals (SAMA 4). Automating the SX X-tie is not suggested given that certain failures in the SX system could fail the non-accident unit if the X-tie is performed without consideration of the failure scenario.

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Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
1SX01PB-----PMFRIE	3.20E-02	1.127	FAILURE OF PUMP 1B TO RUN RANDOMLY	Over 85% of the contribution for this event comes from its combination with JHEP 1RX-JHEP05-HOADA. For cases in which aligning alternate cooling to the charging pump fails, the PDP could be replaced with a self-cooled high pressure injection pump with the capability to auto start on loss of charging flow (SAMA 2). Automating the start of the standby SX pump would also reduce these contributors and may be viable if combined with flooding sensors that would prevent auto start in SX flooding scenarios (SAMA 3). Automating the SX X-tie is not suggested given that certain failures in the SX system could fail the non-accident unit if the X-tie is performed without consideration of the failure scenario. Installation of "no leak" RCP seals is another option (SAMA 4).
1CV-ALL----HPMOA	1.00E-02	1.111	OPERATORS FAIL TO ESTABLISH COOL SUCTION SOURCE FOR CHARGING PUMP	This action represents failure to transfer charging pump suction to the RWST on loss of cooling to the letdown heat exchanger. It is mostly combined with CCW and SX pump failures and pump maintenance unavailabilities, which ultimately lead to seal LOCAs. For cases in which aligning alternate cooling to the charging pump fails, the PDP could be replaced with a self-cooled high pressure injection pump with the capability to auto start on loss of charging flow (SAMA 2). Installation of "no leak" RCP seals is another option (SAMA 4).

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Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
1FP-PRI-7F-HMVRA	4.50E-01	1.106	RECOV OF LOSS OF SX SEAL LOCA (1FP-PRI-7D-HMVRA + 0.21 + 0.1 FP BREAK LOCATION)	These events represent a combination of conditions that preclude recovery of high pressure injection to prevent core damage in fire protection flooding events (alignment fails, break is too large, or break is in a location that precludes use of the FP system). Mitigation of the initiating event could be accomplished by providing shutdown switch for the fire protection pumps in the main control room, which would simplify the action and provide significant time margin for the operators to terminate the flood before critical equipment is lost (SAMA 8). An alternate strategy would be to place flow restrictors in the fire protection pipes to prevent high flow flooding events (SAMA 9). To prevent the seal LOCAs, the PDP could be replaced with a self-cooled high pressure injection pump with the capability to auto start on loss of charging flow (SAMA 2). Installation of "no leak" RCP seals is another option (SAMA 4).
%CCIE	9.60E-01	1.103	INDICATOR FOR CC INITIATING EVENT	These initiating events essentially all lead to RCP seal LOCAs and over 99% are related to the failure to establish a cool suction source for the charging pumps. For cases in which aligning alternate cooling to the charging pump fails, the PDP could be replaced with a self-cooled high pressure injection pump with the capability to auto start on loss of charging flow (SAMA 2). Installation of "no leak" RCP seals is another option (SAMA 4).

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Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
SEAL-U1-TRANS	2.10E-01	1.103	UNIT 1 SEAL LOCA OCCURRED - NON-LOOP SEQUENCES	Over 99% of the non-LOOP seal LOCA contributors include the failure to establish a cool suction source for the charging pump for Loss of CCW initiating events. For cases in which aligning alternate cooling to the charging pump fails, the PDP could be replaced with a self-cooled high pressure injection pump with the capability to auto start on loss of charging flow (SAMA 2). Installation of "no leak" RCP seals is another option (SAMA 4).
1FW-FWR---EHSYOA	1.40E-02	1.101	OPERATORS FAIL TO EXECUTE FW RESTORATION	Over 95% of the contribution from this event is related to two cutsets, both of which are hardware failures that lead to loss of all SX. In these cases, there are no seal LOCAs, but lack of secondary side heat removal requires primary side makeup and when the RWST is depleted, recirc fails due to lack of SX/CC/RHR cooling. If the operators fail to restore feedwater after a loss of SX initiating event, CD ensues due to dependencies. In this case, they are longer term failures, but modifying the Startup FW pump to auto start and align on low SG level (using the AMSAC SG level signal) is a potential means of mitigating this scenario (SAMA 5). A diesel driven SX pump with an auto start function could be used to mitigate CCF failures of the SX pumps. To maximize benefit, backup manual controls would have to be included in the MCR (SAMA 1).

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Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
FLMITIG-M3-T1-FP	6.94E-03	1.077		The events represent the failure to mitigate the fire protection flooding scenarios. Mitigation of the initiating event could be accomplished by providing shutdown switch for the fire protection pumps in the main control room, which would simplify the action and provide significant time margin for the operators to terminate the flood before critical equipment is lost (SAMA 8). An alternate strategy would be to place flow restrictors in the fire protection pipes to prevent high flow flooding events (SAMA 9). To prevent seal LOCAs, the PDP could be replaced with a self-cooled high pressure injection pump with the capability to auto start on loss of charging flow (SAMA 2). Installation of "no leak" RCP seals is another option (SAMA 4). Floods that flow into the Aux Building impact the SX pump rooms via ductwork from the Aux Building drain sump room. Altering the ductwork to eliminate communication between the rooms would help extend the time that is available to mitigate Aux Building flooding events (SAMA 10).

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Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
%FL1FPM3A0----T1	7.58E-04	1.073	UNIT 1 MAJOR FLOOD (>3,700GPM) FROM FIRE PROTECTION INTO AUX BLDG - COMMON AREA	The top 2 cutsets, only differentiated by the heat exchanger alignment, contribute over 97% of the risk for this event. The scenarios include failure to mitigate the flooding event followed by the failure high pressure injection to provide makeup for the seal LOCA (1FP-PRI-7F-HMVRA). Mitigation of the initiating event could be accomplished by providing shutdown switch for the fire protection pumps in the main control room, which would simplify the action and provide significant time margin for the operators to terminate the flood before critical equipment is lost (SAMA 8). An alternate strategy would be to place flow restrictors in the fire protection pipes to prevent high flow flooding events (SAMA 9). To prevent seal LOCAs, which are a dominant consequence of the flood mitigation failure, the PDP could be replaced with a self-cooled high pressure injection pump with the capability to auto start on loss of charging flow (SAMA 2). Installation of "no leak" RCP seals is another option (SAMA 4). Floods that flow into the Aux Building impact the SX pump rooms via ductwork from the Aux Building drain sump room. Altering the ductwork to eliminate communication between the rooms would help extend the time that is available to mitigate Aux Building flooding events (SAMA 10).

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Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
%APIE	9.60E-01	1.067	INDICATOR FOR AP INITIATING EVENT	About 75% of the contribution for this event comes from its combination with 1RX-JHEP05-HOADA or some combination of the events in this dependent action. This 1RX-JHEP05-HOADA represents the failure of 4 different actions: starting the standby CCW/CCP/SX pump (it is the SX pump for these contributors), aligning the inter-unit SX cross-tie, aligning fire protection water to charging pump lube oil cooling, and establishing a cool suction source for the charging pumps. For cases in which aligning alternate cooling to the charging pump fails, the PDP could be replaced with a self-cooled high pressure injection pump with the capability to auto start on loss of charging flow (SAMA 2). Automating the start of the standby SX pump would also reduce these contributors and may be viable if combined with flooding sensors that would prevent auto start in flooding scenarios (SAMA 3). Automating the SX X-tie is not suggested given that certain failures in the SX system could fail the non-accident unit if the X-tie is performed without consideration of the failure scenario. Installation of "no leak" RCP seals is another option (SAMA 4). For the SBO contributors, implementation of the DMS would provide a means of maintaining heat removal and inventory control indefinitely (SAMA 11).

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Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
1AP142------BSLPIE	2.21E-03	1.055	BUS 142 FAILS	Over 97% of the contribution for this event comes from its combination with 1RX-JHEP05-HOADA or some combination of the events in this dependent action. This 1RX-JHEP05-HOADA represents the failure of 4 different actions: starting the standby CCW/CCP/SX pump (it is the SX pump for these contributors), aligning the inter-unit SX cross-tie, aligning fire protection water to charging pump lube oil cooling, and establishing a cool suction source for the charging pumps. For cases in which aligning alternate cooling to the charging pump fails, the PDP could be replaced with a self-cooled high pressure injection pump with the capability to auto start on loss of charging flow (SAMA 2). Automating the start of the standby SX pump would also reduce these contributors and may be viable if combined with flooding sensors that would prevent auto start in flooding scenarios (SAMA 3). Automating the SX X-tie is not suggested given that certain failures in the SX system could fail the non-accident unit if the X-tie is performed without consideration of the failure scenario. Installation of "no leak" RCP seals is another option (SAMA 4). In addition, failure of the AFW cross-tie is a minor contributor, which could be reduced by resolving the regulatory issues related to its use (SAMA 15).

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Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
%RC-MLOC1---PMIE	3.99E-04	1.043	MEDIUM LOCA INITIATING EVENT	Over 90% of the contribution for this event comes from its combination with 0SX007-ES13HMVOA. This action is required at Braidwood because a local manipulation of the _SX007 valve is required when RHR is used to ensure the proper cooling balance is achieved. While it is not unreasonable to expect the RHR/CC temperatures would be closely monitored in the MCR, updating the procedures to explicitly direct an independent check of the valve throttling action would improve the assessed reliability of the action (SAMA 6).
1AP-BOTHSAT-TRMM	6.25E-03	1.042	BOTH U1 SAT OOS FOR TM - 141 PWR VIA 241; 142 PWR VIA 242; 156 - 159 ON UAT	1AP-BOTHSAT-TRMM represents the failure of the UAT to provide power to the 143 bus when both U1 SATs are in maintenance. About 95% of the contribution for this event comes from its combination with loss of service water events, which ultimately results in all SG makeup and RCS injection/heat removal capability. These contributors could be addressed by precluding simultaneous maintenance on both unit SATs or by providing contingency procedures to direct the power alignments required to operate the Startup Feedwater pump (SAMA 12). Alternatively, replacing the PDP with a self-cooled high pressure injection pump with auto start capability would provide a means of maintaining RCP seal injection. For heat removal, the AFW output flow can be routed to the lube oil coolers to eliminate the SX cooling dependence (SAMA 13).

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Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
1RX-JHEP28-HOADA	3.30E-04	1.032	JOINT HEP FOR 1RC-DS-SGTRHDVOA AND 1RC-LCD----HSYOA	This event represents the dependent failure combination of performing RCS cooldown in time to prevent SG overfill (stuck open PORV) followed by failure to cool the RCS down in time to terminate break flow before the RWST is depleted. These events lead directly to core damage. Because of the operator dependence issues in the scenarios including this event, SAMAs requiring manual action would provide limited benefit. A potential means of mitigating these scenarios would be to provide an automated RWST makeup system to ensure injection can be maintained to the RCS for an indefinite period. A source of boration is assumed to be required to prevent re-criticality, which could occur in some conditions if un-borated water is used for RCS makeup (SAMA 14).
1RH-SP-X---HPMOA	7.30E-04	1.031	OPERATORS FAIL TO STOP RH PUMPS	Over 94% of the contribution for this event comes from its combination with the small LOCA initiating event. This contribution is related to the failure to stop the RH pumps when they are on min-flow without CC cooling to the RH heat exchangers. A potential enhancement may be to establish CC to the RH heat exchanger when the RH pumps start (SAMA 7).

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Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
1FP-PRI-7D-HMVRA	3.50E-01	1.03	RECOV OF LOSS OF SX SEAL LOCA (COND PROB OF 1FP-PRI-7D-HMVRA + 0.21 SEAL FAIL)	This is a composite event that represents the probability that either the seal LOCA is too large for the CVCS to mitigate, or that the operators fail to align alternate cooling to the charging pumps in time to protect the RCP seals. Over 55% of the contribution is related to a fire protection system flood in the Aux Building common area. This event could be mitigated by installing fire protection pump controls in the MCR (SAMA 8) or by installing flow restrictors in the fire protection lines (SAMA 9). Another 30% of the contribution is associated with common cause failure of the SX pumps to run with a consequential seal LOCA. A diesel driven SX pump could be used to mitigate CCF failures of the SX pumps. To maximize benefit, controls would have to be included in the MCR (SAMA 1). For cases in which aligning alternate cooling to the charging pump fails, the PDP could be replaced with a self-cooled high pressure injection pump with the capability to auto start on loss of charging flow (SAMA 2). Installation of "no leak" RCP seals is another means of preventing seal LOCAs (SAMA 4).
1CC01PA-B--CPMFRIE	4.96E-04	1.029	CCW PUMPS 1CC01PA & 1CC01PB FAIL TO RUN DUE TO CCF (2/4)	Over 98% of the contribution for this event comes from a single cutset that includes the failure to establish a cool suction source for the charging pumps on loss of CC. The PDP could be replaced with a self-cooled high pressure injection pump with the capability to auto start on loss of charging flow (SAMA 2). Installation of "no leak" RCP seals is another option (SAMA 4).

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Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
1AF-XTIE--EHXVOA	1.00E+00	1.025	OPERATORS FAIL TO EXECUTE AF CROSSTIE FROM OPPOSITE UNIT	This event represents failure of the AFW X-tie, which is assumed to always fail due to regulatory issues. The AFW cross-tie is currently physically in place at the site, but credit cannot be taken for the x-tie capability until permission to fully implement it is granted. Completing the implementation of the AFW X-tie would address the contributors related to this event (SAMA 15).
1CV-ALL-D--HPMRA	3.60E-01	1.023	RECOV OF LOSS OF SX SEAL LOCA (COND PROB OF 1CV-ALL-D-HPMRA + 0.21 SEAL FAIL)	This event represents the probability that either the operators fail to swap the charging pumps to a cool suction source in time to support CCP injection or that the resulting seal LOCA is too large for CCP makeup. Over 90% of the risk is related to scenarios in which all SX pumps fail due to common cause. For these cases, flow from another source needs to be established to the SX piping to cool the loads. A diesel driven SX pump could be used to mitigate CCF failures of the SX pumps. To maximize benefit, controls would have to be included in the MCR (SAMA 1). For cases in which aligning alternate cooling to the charging pump fails, the PDP could be replaced with a self-cooled high pressure injection pump with the capability to auto start on loss of charging flow (SAMA 2). Automating the start of the standby SX pump would also reduce these contributors and may be viable if combined with flooding sensors that would prevent auto start in flooding scenarios (SAMA 3). Installation of "no leak" RCP seals is another means of preventing seal LOCAs (SAMA 4).

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Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
0AP-DLOOP-GT	2.40E-03	1.02	CONDITIONAL PROBABILITY OF DLOOP GIVEN GENERAL TRANSIENT	Over 75% of the contribution for this event comes from its combination with loss of all SX events. A diesel driven SX pump could be used to mitigate CCF failures of the SX pumps. To maximize benefit, controls would have to be included in the MCR. There would be some dependence issues related to using this system, but starting a standby diesel SX pump may be faster and easier than restoring FW for heat removal (SAMA 1). For consequential LOOP paths, RCP seal protection can be pursued, but FW restoration in not available and an alternate form of heat removal is required. Replacing the PDP with a self-cooled high pressure injection pump with auto start capability would provide a means of maintaining RCP seal injection. For heat removal, the AFW output flow can be routed to the lube oil coolers to eliminate the SX cooling dependence (SAMA 13). For the SBO contributors, implementation of the DMS would provide a means of maintaining heat removal and inventory control indefinitely (SAMA 11).

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Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
1SX01AB-----HXFFIE	5.65E-03	1.02	SX PUMP 1B OIL COOLER FAILS DURING OPERATION	Over 88% of the contribution for this event comes from its combination with the dependent failure combination 1RX-JHEP05-HOADA. This JHEP represents the failure of 4 different actions: starting the standby CCW/CCP/SX pump (it is the SX pump for these contributors), aligning the inter-unit SX cross-tie, aligning fire protection water to charging pump lube oil cooling, and establishing a cool suction source for the charging pumps. For cases in which aligning alternate cooling to the charging pump fails, the PDP could be replaced with a self-cooled high pressure injection pump with the capability to auto start on loss of charging flow (SAMA 2). Automating the start of the standby SX pump would also reduce these contributors and may be viable if combined with flooding sensors that would prevent auto start in flooding scenarios (SAMA 3). Automating the SX X-tie is not suggested given that certain failures in the SX system could fail the non-accident unit if the X-tie is performed without consideration of the failure scenario. Installation of "no leak" RCP seals is another option (SAMA 4).

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Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
FLMITIG-M3-T1-WS	3.90E-03	1.019		This event represents the failure to mitigate a flood in the non-essential service water system (>3700 gpm), which includes flood termination before water damage to the SX pumps can occur and for aligning fire protection to the charging pumps for lube oil cooling. The short time frame available for flood termination precludes success of the manual action to shut the WS pumps off even though it is a 1 minute MCR action. Including logic to trip the WS pumps on high flow conditions is a potential means of mitigating the WS flood (SAMA 16). For cases in which aligning alternate cooling to the charging pump fails, the PDP could be replaced with a self-cooled high pressure injection pump with the capability to auto start on loss of charging flow (SAMA 2). Floods that flow into the Aux Building impact the SX pump rooms via ductwork from the Aux Building drain sump room. Altering the ductwork to eliminate communication between the rooms would help extend the time that is available to mitigate Aux Building flooding events (SAMA 10).
1CC01A------HXFFIE	5.34E-03	1.019	CCW HTX 1CC01A - LOSS OF FUNCTION	Over 80% of the contribution for this event comes from its combination with 1RX-JHEP32-HOADA, which represents failure to align a cool suction source for the charging pumps and failure to align the "0" heat exchanger to the unit. For cases in which aligning alternate cooling to the charging pump fails, the PDP could be replaced with a self-cooled high pressure injection pump with the capability to auto start on loss of charging flow (SAMA 2).

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Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
1RX-JHEP32-HOADA	4.90E-04	1.017	JOINT HEP FOR 0CC-HTX0---HHXOA AND 1CV-ALL----HPMOA	Over 85% of the contribution for this event comes from its combination with 1CC01A------HXFFIE, which is the loss of function of the 1CC01A HX. Failure to align the "0" HX in conjunction with failure to align a cool suction source to the charging pumps results in core damage. For cases in which aligning alternate cooling to the charging pump fails, the PDP could be replaced with a self-cooled high pressure injection pump with the capability to auto start on loss of charging flow (SAMA 2). Given that all scenarios including this JHEP are seal LOCA scenarios, installation of "no leak" RCP seals is another option to reduce the frequency of these contributors (SAMA 4).
%FL1WSM3A0----T1	4.23E-04	1.017	UNIT 1 MAJOR FLOOD (>3,700GPM) FROM NORMAL SERVICE WATER INTO AUX BLDG - COMMON	This event represents a flood in the non-essential service water system (>3700 gpm). Over 96% of the contribution comes from a single cutset, which includes the event to mitigate the flood (FLMITIG-M3-T1-WS). Including logic to trip the WS pumps on high flow conditions is a potential means of terminating the WS flood before it damages critical equipment (SAMA 16). For cases in which aligning alternate cooling to the charging pump fails, the PDP could be replaced with a self-cooled high pressure injection pump with the capability to auto start on loss of charging flow (SAMA 2). Floods that flow into the Aux Building impact the SX pump rooms via ductwork from the Aux Building drain sump room. Altering the ductwork to eliminate communication between the rooms would help extend the time that is available to mitigate Aux Building flooding events (SAMA 10).

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Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
1RX-JHEP22-HOADA	1.40E-03	1.015	JOINT HEP FOR 0SX-XTIE---HMVOA AND (1FP-PRI-7X-HMVOA OR 1CV-ALL----HPMOA)	This dependent failure combination represents the failure to align the SX cross-tie and either the failure to align a cool suction source to the charging pumps or to align fire protection to the charging pump lube oil coolers. For cases in which aligning alternate cooling to the charging pump fails, the PDP could be replaced with a self-cooled high pressure injection pump with the capability to auto start on loss of charging flow (SAMA 2). The top 50% of the contributors include evolutions in which SX is lost due to failure of the running pump and failure or maintenance unavailability of the remaining pump. A diesel driven SX pump could be used to mitigate CCF failures of the SX pumps. To maximize benefit, controls would have to be included in the MCR (SAMA 1).

Table F.5-1
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Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
%FL1SX-MA0----T2	1.65E-04	1.015	UNIT 1 MAJOR FLOOD (>2000GPM) FROM SX INTO AUX BLDG - COMMON AREA	This event represents a flood in the essential service water system (>2000 gpm) in the Auxiliary Building, which results in loss of SX and a seal LOCA. Over 65% of the contribution is related to the failure to perform the flood mitigation task of terminating the event before the water level is high enough to fail the charging pumps (among other equipment). This task is for flood termination and alignment of alternate charging pump cooling, which is dominated by failure to align alternate charging pump cooling. For cases in which aligning alternate cooling to the charging pump fails, the PDP could be replaced with a self-cooled high pressure injection pump with the capability to auto start on loss of charging flow (SAMA 2). Floods that flow into the Aux Building impact the SX pump rooms via ductwork from the Aux Building drain sump room. Altering the ductwork to eliminate communication between the rooms would help extend the time that is available to mitigate Aux Building flooding events (SAMA 10).

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Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
0SX-ALL----CSRPGIE	1.57E-05	1.014	SX STRAINERS - PLUGGED DUE TO CCF (4/4)	Over 40% of the contribution for this event comes from its combination with failure to restore FW. A potential means of mitigating this scenario would be to modify the Startup FW pump to auto start and align on low SG level (using the AMSAC SG level signal) (SAMA 5). A diesel driven SX pump with suction from the WS forebay using an alternate, accessible suction strainer in place of the pump discharge strainer could potentially be used to mitigate CCF failures of the existing strainers. To maximize benefit, controls would have to be included in the MCR (SAMA 1). Another 20% of the contribution for this event comes from its combination with simultaneous maintenance of the Unit 1 SATs, which ultimately results in loss of all SG makeup and RCS injection/heat removal capability. These contributors could be addressed by precluding simultaneous maintenance on both unit SATs or by providing contingency procedures to direct the power alignments required to operate the Startup Feedwater pump (SAMA 12). About 15% of the contribution is associated with failure to align alternate charging pump cooling. For cases in which aligning alternate cooling to the charging pump fails, the PDP could be replaced with a self-cooled high pressure injection pump with the capability to auto start on loss of charging flow (SAMA 2).

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Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
1FW-FRH1---HSGOA	1.10E-03	1.014	OPERATORS FAIL RECOGNIZE THE CUE TO SECONDARY COOLING	These events represent the failure to recognize the need to align an alternate heat removal source (AFW X-tie, FW Restoration, or bleed and feed) after failure of AFW. The action itself is relatively reliable, has an alarmed cue, and clear procedure guidance. A larger contributor to the cognitive element is that the procedure step is not graphically distinct, but changing the procedure to include an emphasis on the step is not judged to provide more than an academic benefit. Nearly 50% of the contribution is related to total loss of SX due to pump CCF and strainer plugging. A diesel driven SX pump with an auto start function could be used to mitigate CCF failures of the SX pumps. To maximize benefit, backup manual controls would have to be included in the MCR (SAMA 1).
1CC01PAB2A-CPMFRIE	2.37E-04	1.014	CCW PUMPS 1CC01PA/1CC01PB/2CC01PA FAIL TO RUN DUE TO CCF (3/4)	Over 98% of the contribution for this event comes from its combination with the failure to align a cool suction source to the charging pump. The PDP could be replaced with a self-cooled high pressure injection pump with the capability to auto start on loss of charging flow (SAMA 2).
1CC01PAB2B-CPMFRIE	2.37E-04	1.014	CCW PUMPS 1CC01PA/1CC01PB/2CC01PB FAIL TO RUN DUE TO CCF (3/4)	Over 98% of the contribution for this event comes from its combination with the failure to align a cool suction source to the charging pump. The PDP could be replaced with a self-cooled high pressure injection pump with the capability to auto start on loss of charging flow (SAMA 2).

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Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
0AP-DLOOP-SC	6.70E-01	1.014	FRACTION OF CONDITIONAL LOOPS THAT ARE SWITCHYARD-CENTERED	The largest single contributor (about 69%) including this event is initiated by a CCF of all SX pumps. A diesel driven SX pump could be used to mitigate CCF failures of the SX pumps. To maximize benefit, controls would have to be included in the MCR (SAMA 1). There would be some dependence issues related to using this system, but starting a standby diesel SX pump may be faster and easier than restoring FW for heat removal. For consequential LOOP paths, RCP seal protection can be pursued, but FW restoration in not available and an alternate form of heat removal is required. Replacing the PDP with a self-cooled high pressure injection pump with auto start capability would provide a means of maintaining RCP seal injection. For heat removal, the AFW output flow can be routed to the lube oil coolers to eliminate the SX cooling dependence (SAMA 13). For the SBO contributors, implementation of the DMS would provide a means of maintaining heat removal and inventory control indefinitely (SAMA 11).
1AF01PB-----PDMM	1.05E-02	1.014	AF DIESEL-DRIVEN PUMP 1AF01PB UNAVAILABLE DUE TO MAINTENANCE	About 48% of the contribution from this event includes failure of the AFW X-tie in conjunction with loss of DC buss 111 (which fails the motor driven auxiliary feedwater pump and FW condensate). The AFW cross-tie is currently physically in place at the site, but credit cannot be taken for the x-tie capability until regulatory issues are resolved and implementation is finalized. Completing the implementation of the AFW X-tie would address the contributors related to this event (SAMA 15).

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Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
%DC-LODC111-BSIE	5.37E-04	1.014	LOSS OF DC BUS 111 INITIATING EVENT	Over 87% of the contribution for this event comes from its combination with the failure to perform the AFW X-tie. Loss of DC buss 111 in conjunction with maintenance of the AFW B pump is a dominant contributor to the loss of the AFW function. Completing the implementation of the AFW X-tie would address the contributors related to this event (SAMA 15).
%FW-GTR-1---HWIE	7.30E-01	1.013	GENERAL TRANSIENT INITIATING EVENT	The failure evolutions initiated by the general transient initiator are diverse and there is no single dominant contributor to risk. The largest contributor (about 35%) is from a joint human error representing the failure to refill the diesel driven fuel oil tank with a subsequent failure to identify the loss of SG makeup and to take corrective action. These events can be addressed by automating the diesel driven AFW fuel oil tank refill function (SAMA 18). For the cases in which the AFW hardware fails, the AFW cross-tie will provide alternate Sg makeup capability (SAMA 15).

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Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
%SP-BB-A-SXPRB-1	1.21E-03	1.013	GLOBAL SPRAY SCENARIO UNIT 1 BYRON AND BRAIDWOOD IN AUX BLDG - SX PUMP ROOM B	The "B" SX pump is failed by direct spray from a pipe break within the pump room. Pump damage could potentially be prevented by installing spray shields on the SX pump, but even if the pump is protected, the event would lead to a forced shutdown without the "B" SX pump when the break is discovered. A manual trip is preferable to an automatic trip, but the benefit of the spray shield is questionable. Over 88% of the contribution including this initiating event is associated with dependent failure event 1RX-JHEP05-HOADA. The PDP could be replaced with a self-cooled high pressure injection pump with the capability to auto start on loss of charging flow (SAMA 2). Installation of "no leak" RCP seals is another option (SAMA 4). Automating the start of the standby SX pump (SAMA 3) would provide a means of supplying SX to required loads, but depending on where the pipe break is, the SX system may be shut down for evaluation and this capability would provide no benefit.

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Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
FLMITIG--G-T1-FP	2.23E-04	1.012		The event represents failure to terminate the fire protection flood in the aux building. The scenarios including this event could be mitigated by installing fire protection pump controls in the MCR (SAMA 8) or by installing flow restrictors in the fire protection lines (SAMA 9). For fire protection breaks, there is a chance that the break is in an area that would preclude use of the fire protection system as an alternate cooling source for charging pump lube oil cooling, but for those cases in which the break does not prevent use of the system, the PDP could be replaced with a self-cooled high pressure injection pump with the capability to auto start on loss of charging flow (SAMA 2). An alternate means of preventing a seal LOCA would be to install "no leak" seals (SAMA 4). Floods that flow into the Aux Building impact the SX pump rooms via ductwork from the Aux Building drain sump room. Altering the ductwork to eliminate communication between the rooms would help extend the time that is available to mitigate Aux Building flooding events (SAMA 10).

Table F.5-1
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Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
%FL1FP-GA0----T1	3.99E-03	1.012	UNIT 1 GENERAL FLOOD (100-2000GPM) FROM FIRE PROTECTION INTO AUX BLDG - COMMON A	This event represents the occurrence of a fire protection flood in the aux building. The scenarios including this event could be mitigated by installing fire protection pump controls in the MCR (SAMA 8) or by installing flow restrictors in the fire protection lines (SAMA 9). For fire protection breaks, there is a chance that the break is in an area that would preclude use of the fire protection system as an alternate cooling source for charging pump lube oil cooling, but for those cases in which the break does not prevent use of the system, the PDP could be replaced with a self-cooled high pressure injection pump with the capability to auto start on loss of charging flow (SAMA 2). An alternate means of preventing a seal LOCA would be to install "no leak" seals (SAMA 4). Floods that flow into the Aux Building impact the SX pump rooms via ductwork from the Aux Building drain sump room. Altering the ductwork to eliminate communication between the rooms would help extend the time that is available to mitigate Aux Building flooding events (SAMA 10).

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Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
FLMITIG-M2-T1-FP	2.19E-03	1.011		The event represents failure to terminate the fire protection flood in the aux building. The scenarios including this event could be mitigated by installing fire protection pump controls in the MCR (SAMA 8) or by installing flow restrictors in the fire protection lines (SAMA 9). For fire protection breaks, there is a chance that the break is in an area that would preclude use of the fire protection system as an alternate cooling source for charging pump lube oil cooling, but for those cases in which the break does not prevent use of the system, the PDP could be replaced with a self-cooled high pressure injection pump with the capability to auto start on loss of charging flow (SAMA 2). An alternate means of preventing a seal LOCA would be to install "no leak" seals (SAMA 4). Floods that flow into the Aux Building impact the SX pump rooms via ductwork from the Aux Building drain sump room. Altering the ductwork to eliminate communication between the rooms would help extend the time that is available to mitigate Aux Building flooding events (SAMA 10).

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Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
%FL1FPM2A0----T1	3.77E-04	1.011	UNIT 1 MAJOR FLOOD M2 (3,700GPM) FROM FIRE PROTECTION INTO AUX BLDG - COMMON ARE	The event represents the occurrence of a fire protection flood in the aux building. The scenarios including this event could be mitigated by installing fire protection pump controls in the MCR (SAMA 8) or by installing flow restrictors in the fire protection lines (SAMA 9). For fire protection breaks, there is a chance that the break is in an area that would preclude use of the fire protection system as an alternate cooling source for charging pump lube oil cooling, but for those cases in which the break does not prevent use of the system, the PDP could be replaced with a self-cooled high pressure injection pump with the capability to auto start on loss of charging flow (SAMA 2). An alternate means of preventing a seal LOCA would be to install "no leak" seals (SAMA 4). Floods that flow into the Aux Building impact the SX pump rooms via ductwork from the Aux Building drain sump room. Altering the ductwork to eliminate communication between the rooms would help extend the time that is available to mitigate Aux Building flooding events (SAMA 10).

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Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
1FP-PRI-7X-HMVOA	4.60E-03	1.011	OPERATORS FAIL TO ALIGN FP SEAL COOLING - SX NON-PIPE FAILURE INITIATOR	Over 95% of the contribution for this event comes from its combination with the Loss of SX initiating event, either all pumps on both units or al SX strainer on both units. A diesel driven SX pump with an auto start function could be used to mitigate CCF failures of the SX pumps. To maximize benefit, backup manual controls would have to be included in the MCR (SAMA 1). Another potential means of mitigating this scenario would be to modify the Startup FW pump to auto start and align on low SG level (using the AMSAC SG level signal) (SAMA 5). For cases in which aligning alternate cooling to the charging pump fails, the PDP could be replaced with a self-cooled high pressure injection pump with the capability to auto start on loss of charging flow (SAMA 2). An alternate means of preventing a seal LOCA would be to install "no leak" seals (SAMA 4).
%RC-SGTR1-A-HXIE	8.41E-04	1.01	STEAM GENERATOR TUBE RUPTURE IN S/G 1A	Over 75% of the contribution from this event is tied to the dependent human failure combination of failing to cool the RCS in time to prevent opening a SG PORV (lead to stuck open PORV) and the subsequent failure to cool the RCS to terminate flow from the break before RWST depletion. Installing an automated RWST makeup system that would extend the time available to perform the cooldown would provide additional time for action and, if the actuation is alarmed, it would provide an additional cue to perform the RCS cooldown (SAMA 14).

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Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
%RC-SGTR1-B-HXIE	8.41E-04	1.01	STEAM GENERATOR TUBE RUPTURE IN S/G 1B	Over 75% of the contribution from this event is tied to the dependent human failure combination of failing to cool the RCS in time to prevent opening a SG PORV (lead to stuck open PORV) and the subsequent failure to cool the RCS to terminate flow from the break before RWST depletion. Installing an automated RWST makeup system that would extend the time available to perform the cooldown would provide additional time for action and, if the actuation is alarmed, it would provide an additional cue to perform the RCS cooldown (SAMA 14).
%RC-SGTR1-C-HXIE	8.41E-04	1.01	STEAM GENERATOR TUBE RUPTURE IN S/G 1C	Over 75% of the contribution from this event is tied to the dependent human failure combination of failing to cool the RCS in time to prevent opening a SG PORV (lead to stuck open PORV) and the subsequent failure to cool the RCS to terminate flow from the break before RWST depletion. Installing an automated RWST makeup system that would extend the time available to perform the cooldown would provide additional time for action and, if the actuation is alarmed, it would provide an additional cue to perform the RCS cooldown (SAMA 14).

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Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
%RC-SGTR1-D-HXIE	8.41E-04	1.01	STEAM GENERATOR TUBE RUPTURE IN S/G 1D	Over 75% of the contribution from this event is tied to the dependent human failure combination of failing to cool the RCS in time to prevent opening a SG PORV (lead to stuck open PORV) and the subsequent failure to cool the RCS to terminate flow from the break before RWST depletion. Installing an automated RWST makeup system that would extend the time available to perform the cooldown would provide additional time for action and, if the actuation is alarmed, it would provide an additional cue to perform the RCS cooldown (SAMA 14).
1RX-JHEP47-HOADA	3.30E-04	1.01	JOINT HEP FOR 1RC-PUMPS--HPMOA AND 0SX005-----HMVOA AND 1FP-PRI-7X-HMVOA	Over 97% of the contribution for this event comes from its combination with 1AP142------BSLPIE, which is the loss of Bus 142. The combined operator failures to start the standby SX pump, align the SX x-tie given loss of power, and failure to align alternate cooling to the charging pumps results in an RCP seal LOCA without a heat sink. The PDP could be replaced with a self-cooled high pressure injection pump with the capability to auto start on loss of charging flow (SAMA 2). Automating the start of the standby SX pump would also reduce these contributors (SAMA 3). Installation of "no leak" RCP seals is another option (SAMA 4).

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Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
1RX-JHEP48-HOADA	3.30E-04	1.01	JOINT HEP FOR 1RC-PUMPS--HPMOA AND 0SX005-----HMVOA AND 1CV-ALL----HPMOA	Over 97% of the contribution for this event comes from its combination with 1AP142------BSLPIE, which is the loss of Bus 142. The combined operator failures to start the standby SX pump, align the SX x-tie given loss of power, and failure to align the charging pumps to a cool suction source results in an RCP seal LOCA without a heat sink. The PDP could be replaced with a self-cooled high pressure injection pump with the capability to auto start on loss of charging flow (SAMA 2). Automating the start of the standby SX pump would also reduce these contributors (SAMA 3). Installation of "no leak" RCP seals is another option (SAMA 4).
1SX01PA-----PMMM	1.05E-02	1.01	SX PUMP 1A UNAVAILABLE DUE TO MAINTENANCE	About 70% of the contribution for this event comes from its combination with 1RX-JHEP22-HOADA or some combination of the events in this dependent failure combination. 1RX-JHEP22-HOADA represents the failure to align the SX cross-tie and either the failure to align a cool suction source to the charging pumps or to align fire protection to the charging pump lube oil coolers. For cases in which aligning alternate cooling to the charging pump fails, the PDP could be replaced with a self-cooled high pressure injection pump with the capability to auto start on loss of charging flow (SAMA 2). A diesel driven SX pump could be used to mitigate CCF failures of the SX pumps. To maximize benefit, controls would have to be included in the MCR (SAMA 1).

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Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
1SI-HPR----HSYOA	6.80E-03	1.01	OPERATORS FAIL TO ESTABLISH HIGH PRESSURE RECIRC (SLOW EVENT)	There is not a single dominant event related to the scenarios that include this event, but failure of the AFW system is the condition that drives the need for recirculation mode. 38% of the contribution is directly tied to the failure of the AFW X-tie. Completing the implementation of the AFW X-tie would address the contributors related to this event (SAMA 15). Failure of the AFW system requires transition to an alternate method of heat removal, however, if the startup FW pump is enhanced to autostart on AFW failure, the importance of the action to manually align the startup feedwater would be reduced (SAMA 5). The current configuration requires a manual restart of MFW as a backup heat removal source. Automating swap to recirculation mode is an additional potential enhancement (SAMA 30).

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Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
FLMITIG--M-T2-SX	2.09E-03	1.01		This event represents the failure to mitigate a flood in the essential service water system (>2000 gpm) in the Auxiliary Building, which results in loss of SX and a seal LOCA. The contribution is represented by a single cutset. Failure to perform the flood mitigation task of terminating the event before the water level is high enough to fail the charging pumps (among other equipment) or failure to align alternate charging pump lube oil cooling results in core damage. This task is for flood termination and alignment of alternate charging pump cooling, which is dominated by failure to align alternate charging pump cooling. For cases in which aligning alternate cooling to the charging pump fails, the PDP could be replaced with a self-cooled high pressure injection pump with the capability to auto start on loss of charging flow (SAMA 2). An alternate means of preventing a seal LOCA would be to install "no leak" seals (SAMA 4).
1AF01PA-----PMMM	4.31E-03	1.009	AF MOTOR-DRIVEN PUMP 1AF01PA UNAVAILABLE DUE TO MAINTENANCE	Over 69% of the contributors include either the independent failure of 1FW-FRH1---HSGOA or a joint HEP that includes the action. A potential means of mitigating this scenario would be to modify the Startup FW pump to auto start and align on low SG level (using the AMSAC SG level signal) (SAMA 5). Another contributor in a dependent action chain (about 47%) is for the action to refill the diesel driven AFW pump fuel oil day tank. Automating the refuel function is a potential means of reducing the contribution of these events (SAMA 18).

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Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
1SX01FB-2---SRPGIE	2.51E-03	1.009	SX STRAINER 1SX01FB-2 PLUGGED	Over 89% of the contribution for this event comes from its combination with JHEP 1RX-JHEP05-HOADA. The PDP could be replaced with a self-cooled high pressure injection pump with the capability to auto start on loss of charging flow (SAMA 2). Automating the start of the standby SX pump would also reduce these contributors and may be viable if combined with flooding sensors that would prevent auto start in SX flooding scenarios (SAMA 3). Automating the SX X-tie is not suggested given that certain failures in the SX system could fail the non-accident unit if the X-tie is performed without consideration of the failure scenario. Installation of "no leak" RCP seals is another option (SAMA 4).

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Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
%FW-LMFW1---HWIE	6.88E-02	1.009	TOTAL LOSS OF MAIN FEEDWATER	The failure evolutions initiated by the total loss of MFW initiator are diverse and there is no single dominant contributor to risk. In many cases, the AFW function is lost due to hardware failures, which is followed by a failure to swap to recirculation mode (27%). Fully automating the swap to recirculation mode could mitigate these contributors (SAMA 30). Alternatively, installing an automated RWST makeup system that would extend the time available to perform the transition to recirculation. If the actuation is alarmed, it would provide an additional cue to perform the action (SAMA 14). Over 13% of the contributors also include the failure of the operator to throttle the _SX007 valves for recirculation cooling. While it is not unreasonable to expect the RHR/CC temperatures would be closely monitored in the MCR, updating the procedures to explicitly direct an independent check of the valve throttling action would improve the assessed reliability of the action (SAMA 6).
0CCPUMPALL-CPMFRIE	1.46E-04	1.008	ALL CCW PUMPS FAIL TO RUN DUE TO CCF (4/4)	Over 99% of the scenarios including this event also include the failure to align a cool suction source to the charging pump. The PDP could be replaced with a self-cooled high pressure injection pump with the capability to auto start on loss of charging flow (SAMA 2). Installation of "no leak" RCP seals is another option to prevent the seal LOCA (SAMA 4).

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Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
1AF01PA-B--CPMFR	8.20E-05	1.008	AF PUMPS FAIL TO RUN DUE TO CCF (2/2)	Over 32% of the contribution is related to the failure to recognize the need to start an alternate heat removal system after AFW failure. Failure of the AFW system requires transition to an alternate method of heat removal, however, if the Startup FW pump is modified to auto start and align on low SG level (using the AMSAC SG level signal), the risk of this scenario could be reduced (SAMA 5). The current configuration requires a manual restart of MFW as a backup heat removal source. Other contributors include failure to perform the AFW X-tie and alignment of high pressure recirculation mode. The AFW X-tie is currently physically in place at the site, but credit cannot be taken for the x-tie capability until permission to fully implement it is granted. Completing the implementation of the AFW X-tie would address the contributors related to this event (SAMA 15). For the cases that include failure to swap to recirculation, this action is only required because of loss of AFW. Making the AFW X-tie available would also address most of these cases.

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Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
%RCS-RHR-DISCHIE	9.16E-07	1.007	FREQ OF EXPOSING RHR PUMP DISCHARGE HEADERS TO RCS PRESSURE	This event is a piping overpressurization event that leads to ISLOCA scenarios and core damage (and containment bypass). Over 99% of the contribution is due to a single cutset that represents the conditional probability of a leak when the RHR line is subjected to high pressure. Potential enhancements include installing pressure monitoring instrumentation in the RHR lines or replacing the MOV in the suction line with a valve capable of closing against RCS pressure. Success of the pressure monitoring instruments is predicted on a leak before break failure mode that would allow sufficient time to shut down the reactor and depressurize the RCS before both check valves fail. For the large flow breaks represented by this event, it is not clear that pressure monitoring would provide adequate warning to mitigate the event and it is not considered to be a comprehensive means of reducing the frequency of these events. The ISLOCA analysis indicates that the isolation MOVs in the cold and hot legs are not designed to close against RCS pressure. A potential means of addressing these ISLOCA scenarios would be to replace MOVs _SI8809A, _SI8809B, and _SI8840 with valves that could be used to terminate an ISLOCA event (SAMA 19).

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Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
LEAK-800-150	2.80E-01	1.007	CONDITIONAL PROB OF LEAK 800 GPM GIVEN LEAK IS AT LEAST 150 GPM	This event represents the probability that an ISLOCA occurs given exposure the RHR line to overpressure conditions, 100% of which leads directly to core damage (and containment bypass). The ISLOCA analysis indicates that the isolation MOVs in the cold and hot legs are not designed to close against RCS pressure. A potential means of addressing these ISLOCA scenarios would be to replace MOVs _SI8809A, _SI8809B, and _SI8840 with valves that could be used to terminate an ISLOCA event (SAMA 19).
1RX-JHEP17-HOADA	3.60E-05	1.007	JOINT HEP FOR 1AF01PB-FO-HXVOA AND 1FW-FRH1---HSGOA	These are long term scenarios in which diesel driven AFW fuel oil refill fails followed by failure to recognize the need for alternate heat removal. Automating the refuel function is a potential means of reducing the contribution of these events (SAMA 18).
1AP141------BSLPIE	2.21E-03	1.007	BUS 141 FAILS	About 30% of the cases include unavailability of the "B" train AFW pump and failure of the AFW X-tie. Completing the implementation of the AFW X-tie would address these contributors (SAMA 15). About 65% of the contributors are cases in which seal cooling is lost followed by the onset of a seal LOCA. The DMS would provide a means of addressing these contributors (SAMA 11).

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Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
%CD-LCND1---HWIE	5.44E-02	1.006	LOSS OF CONDENSER HEAT SINK	There is not a single dominant event related to the scenarios that include this event, but failure of the AFW system is the condition that drives the need for recirculation mode. Given the loss of the condenser initiating event, use of MFW is not an option for this scenario. In addition, the timing prevents use of the AFW x-tie. Failure to swap to recirc mode is another contributor at about 30% of the total for this event. Fully automating the swap to recirculation mode could mitigate these contributors (SAMA 30). Alternatively, installing an automated RWST makeup system that would extend the time available to perform the transition to recirculation. If the actuation is alarmed, it would provide an additional cue to perform the action (SAMA 14).
1RH01PB-----PMMM	9.80E-03	1.006	RH PUMP 1RH01PB UNAVAILABLE DUE TO MAINTENANCE	One on the larger contributors (about 53%) is related to failure of the AFW X-tie. Completing the implementation of the AFW X-tie would address the contributors related to this event (SAMA 15). Failure of the AFW system requires transition to an alternate method of heat removal, however, if the Startup FW pump is modified to auto start and align on low SG level (using the AMSAC SG level signal), the risk from this scenario could be reduced (SAMA 5). The current configuration requires a manual restart of MFW as a backup heat removal source.

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Braidwood Level 1 IE Importance List Review

Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
1RY-PORV---HPVOA	2.50E-02	1.005	OPERATORS FAIL TO PREVENT WATER CHALLENGE TO PZR PORVs	Over 81% of the contributors also include the failure of the operator to throttle the _SX007 valves for recirculation cooling. While it is not unreasonable to expect the RHR/CC temperatures would be closely monitored in the MCR, updating the procedures to explicitly direct an independent check of the valve throttling action would improve the assessed reliability of the action (SAMA 6). The action to prevent the water challenge itself has clear procedural guidance and it is familiar to the operators. The HEP may be conservative in that it does not credit potential error recovery steps due to the timing conditions; however, the current evaluation uses a procedure step as the cue for the action rather than SI initiation, which could be considered the start of the cognitive process for assessing the need for SI in the relevant scenarios. No SAMAs have been identified directly related to this action.
1CC01PB----HOEXM	8.00E-04	1.005	CC PUMP TRAIN 1B VALVE MISALIGNED POST T&M (STANDBY ONLY)	About 65% of the contribution is related to failure of the operator to swap the charging pumps to alternate cooling on loss of CCW, which results in a seal LOCA. The PDP could be replaced with a self-cooled high pressure injection pump with the capability to auto start on loss of charging flow to prevent the seal LOCA (SAMA 2). An alternate means of preventing a seal LOCA would be to install "no leak" seals (SAMA 4). An additional 20% of the contributors include the failure to perform the AFW X-tie. Completing the implementation of the AFW X-tie would address the contributors related to this event (SAMA 15).

Table F.5-1
Braidwood Level 1 IE Importance List Review

Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
1CC01PA-----PMFRIE	7.18E-02	1.005	CCW PUMP 1CC01PA RANDOMLY FAILS TO CONTINUE TO RUN	Over 99% of the scenarios including this event also include the failure to align a cool suction source to the charging pump. The PDP could be replaced with a self-cooled high pressure injection pump with the capability to auto start on loss of charging flow (SAMA 2). Installation of "no leak" RCP seals is another option to prevent the seal LOCA (SAMA 4).
1FW02P------PMMM	1.58E-02	1.005	MFW MD START UP PUMP FW02P UNAVAILABLE DUE TO MAINTENANCE	Over 98% of the contribution for this event comes from its combination with the Loss of SX initiating event, either all pumps on both units or al SX strainer on both units. A diesel driven SX pump with an auto start function could be used to mitigate CCF failures of the SX pumps. To maximize benefit, backup manual controls would have to be included in the MCR (SAMA 1). For cases in which aligning alternate cooling to the charging pump fails, the PDP could be replaced with a self-cooled high pressure injection pump with the capability to auto start on loss of charging flow (SAMA 2). An alternate means of preventing a seal LOCA would be to install "no leak" seals (SAMA 4).

Table F.5-1
Braidwood Level 1 IE Importance List Review

Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
1AF01PB-----PDFS	2.71E-03	1.005	DIESEL-DRIVEN PUMP 1AF01PB RANDOM FAILURE TO START	There is not a single dominant event related to the scenarios that include this event, but failure of the AFW system is the condition that drives the need for recirculation mode. Over 55% of the contribution is directly tied to the failure of the AFW X-tie. Completing the implementation of the AFW X-tie would address the contributors related to this event (SAMA 15). Failure of the AFW system requires transition to an alternate method of heat removal, however, if the Startup FW pump is modified to auto start and align on low SG level (using the AMSAC SG level signal), the risk of this scenario could be reduced (SAMA 5). The current configuration requires a manual restart of MFW as a backup heat removal source.

Table F.5-2a
Braidwood LERF Importance List Review

Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
%SXIE	9.60E-01	1.39	INDICATOR FOR SX INITIATING EVENT	Addressed in the Level 1 importance list.
%RCS-RHR-DISCHIE	9.16E-07	1.325	FREQ OF EXPOSING RHR PUMP DISCHARGE HEADERS TO RCS PRESSURE	Addressed in the Level 1 importance list.
LEAK-800-150	2.80E-01	1.323	CONDITIONAL PROB OF LEAK 800 GPM GIVEN LEAK IS AT LEAST 150 GPM	Addressed in the Level 1 importance list.

Table F.5-2a
Braidwood LERF Importance List Review

Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
1L2-SGT-VF-PISGR	2.80E-02	1.319	PRESSURE-INDUCED STEAM GENERATOR TUBE RUPTURE	About 85% of the contributors are loss of SX initiators or events that lead to loss of SX followed by unavailability of main FW. A diesel driven SX pump with an auto start function could be used to mitigate CCF failures of the SX pumps. To maximize benefit, backup manual controls would have to be included in the MCR (SAMA 1). For cases in which aligning alternate cooling to the charging pump fails, the PDP could be replaced with a self-cooled high pressure injection pump with the capability to auto start on loss of charging flow (SAMA 2). For the contributors in which the failure of SX is due to the failure to start the standby SX pump, automating the start of the standby SX pump on failure of the running pump is a potential solution (SAMA 3). Instead of replacing the PDP to protect the RCP seals, a passive means of preventing a seal LOCA would be to install "no leak" RCP seals (SAMA 4). Another potential means of mitigating this scenario would be to modify the Startup FW pump to auto start and align on low SG level (using the AMSAC SG level signal) (SAMA 5). For the induced tube rupture event itself, the condition of the SG tubes does play a role in the determination of the failure probability, but SG replacement is already in progress at the site and no additional changes are suggested.

Table F.5-2a
Braidwood LERF Importance List Review

Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
1RH-FAILS	1.00E+00	1.285	RH PUMPS FAIL DURING RECIRC MODE (WITH CS IN RECIRCULATION MODE)	These failures are essentially all related to containment isolation failure scenarios. There are a number of isolation failure mechanisms, the largest of which is an operator error related to the failure to close the path between the RWST and the containment sump (1CI-RWST---HMVOA at 40%). The operator action evaluation is based on closing the required valves as part of the transition to recirculation mode and does not credit the additional isolation tasks that would close the relevant release pathway that are performed in the SACRG-1 procedure. The SACRG-1 isolation tasks, which are directed by a different procedure, based on different cues, and taken at a different time than the credited isolation actions could be credited to reduce the risk associated with this event. No additional procedural changes are considered to be required. The scenarios leading to the containment isolation failures include the same contributors reviewed in the Level 1 importance list (e.g., %SXIE 38%, %RC-SLOC1-N-PSIE 18%, %CCIE 10%, %APIE 10%) and the same SAMAs are applicable. No additional SAMAs are suggested.
0SX01AB2AB-CPMFRIE	2.16E-04	1.271	FAILURE OF ALL SX PUMPS (1A/1B/2A/2B) TO RUN DUE TO CCF (4/4)	Addressed in the Level 1 importance list.

Table F.5-2a
Braidwood LERF Importance List Review

Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
1FW-FWR---EHSYOA	1.40E-02	1.135	OPERATORS FAIL TO EXECUTE FW RESTORATION	Addressed in the Level 1 importance list.
1CI-RWST---HMVOA	3.00E-03	1.098	OPERATORS FAIL TO CLOSE MOV SI8806 OR CV112D/E OR SI8813/8920 OR 8814	This event represents a containment isolation failure due to an operator error related to the failure to close the path between the RWST and the containment sump. The operator action evaluation is based on closing the required valves as part of the transition to recirculation mode and does not credit the additional isolation tasks that would close the relevant release pathway that are performed in the SACRG-1 procedure. The SACRG-1 isolation tasks, which are directed by a different procedure, based on different cues, and taken at a different time than the credited isolation actions could be credited to reduce the risk associated with this event. No additional procedural changes are considered to be required. The scenarios leading to the containment isolation failures include the same contributors reviewed in the Level 1 importance list (e.g., %SXIE 40%, %RC-SLOC1-N-PSIE 19%, %CCIE 10%, %FL1FPM3A0----T1 8%) and the same SAMAs are applicable. No additional SAMAs are suggested.
FLAG-CCHTX0-U2	5.00E-01	1.088	CCW HTX 0 ALIGNED TO UNIT 2	Addressed in the Level 1 importance list.
1FP-PRI-7D-HMVRA	3.50E-01	1.082	RECOV OF LOSS OF SX SEAL LOCA (COND PROB OF 1FP-PRI-7D-HMVRA + 0.21 SEAL FAIL)	Addressed in the Level 1 importance list.

Table F.5-2a
Braidwood LERF Importance List Review

Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
0SX007-ES13HMVOA	3.40E-03	1.082	OPERATORS FAIL TO LOCALLY THROTTLE SX007 TO CC HXS	Addressed in the Level 1 importance list.
FLMITIG-M3-T1-WS	3.90E-03	1.077		Addressed in the Level 1 importance list.
1CI-CLASS-A-PNFF	2.30E-03	1.075	CLASS A PENTRATION FAILURE	This event represents a containment isolation failure due to any/all penetration failures and is not associated with any specific penetration failure or weakness. This type of a general event does not provide meaningful insight into a specific enhancement that could be made to the penetration itself. The frequency of the scenarios that lead to core damage, however, can be reduced. All contributors above at least 2%of the portion of the CDF that includes this event are included in the L1 importance review, including %SXIE(40%), FLAG-CCHTX0-U2 (23%), 0SX007-ES13HMVOA (22%), 0SX01AB2AB-CPMFRIE (22%), and %RC-SLOC1-N-PSIE (21%). SAMAs related to these events would be relevant to reducing the risk of the scenarios that include 1CI-CLASS-A-PNFF.
FLAG-CCHTX0-U1	5.00E-01	1.069	CCW HTX 0 ALIGNED TO UNIT 1	Addressed in the Level 1 importance list.

Table F.5-2a
Braidwood LERF Importance List Review

Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
%RCS-RHR-SUCT-IE	4.58E-07	1.066	FREQUENCY OF HAVING RCS PRESSURE IN THE RHR SUCTION LINE	This event is a piping overpressurization event that leads to ISLOCA scenarios, core damage, and containment bypass. Over 98% of the contribution is due to a single cutset that represents the conditional probability of a leak that is at least 1700 gpm given a leak of 150 gpm when the RHR line is subjected to high pressure. The leak path is due to failure of two MOVs that are in series between the RHR pump suction and the RCS hot leg. There are currently no other valves in the suction path line that could be used to isolate flow. Potential enhancements include installing pressure monitoring instrumentation in the RHR lines or installing an emergency isolation valve in the suction line. Success of the pressure monitoring instruments is predicted on a leak before break failure mode that would allow sufficient time to shut down the reactor and depressurize the RCS before both isolation valves fail. For the large flow breaks represented by this event, it is not clear that pressure monitoring would provide adequate warning to mitigate the event and it is not considered to be a comprehensive means of reducing the frequency of these events. Therefore, installing an emergency isolation valve is suggested as a means of mitigating this sequence (SAMA 21).

Table F.5-2a
Braidwood LERF Importance List Review

Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
LEAK-1700-150	1.40E-01	1.065	CONDITIONAL PROB OF LEAK 1700 GPM GIVEN LEAK IS AT LEAST 150 GPM	This event represents the conditional probability of a leak that is at least 1700 gpm given a leak of 150 gpm when the RHR line is subjected to high pressure. The leak path is due to failure of two MOVs that are in series between the RHR pump suction and the RCS hot leg. There are currently no other valves in the suction path line that could be used to isolate flow. Potential enhancements include installing pressure monitoring instrumentation in the RHR lines or installing an emergency isolation valve in the suction line. Success of the pressure monitoring instruments is predicted on a leak before break failure mode that would allow sufficient time to shut down the reactor and depressurize the RCS before both isolation valves fail. For the large flow breaks represented by this event, it is not clear that pressure monitoring would provide adequate warning to mitigate the event and it is not considered to be a comprehensive means of reducing the frequency of these events. Therefore, installing an emergency isolation valve is suggested as a means of mitigating this sequence (SAMA 21).
%RC-SLOC1-N-PSIE	1.40E-03	1.064	SMALL LOCA INITIATING EVENT (NON-ISOLABLE)	Addressed in the Level 1 importance list.

Table F.5-2a
Braidwood LERF Importance List Review

Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
1RX-JHEP05-HOADA	3.30E-04	1.063	JHEP - 1RC-PUMPS--HPMOA/0SX-XTIE---HMVOA/(1FP-PRI-7X-HMVOA OR 1CV-ALL----HPMOA)	Addressed in the Level 1 importance list.

Table F.5-2a
Braidwood LERF Importance List Review

Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
1AF-SGFLOODHPVOA	4.10E-02	1.06	Operator Maintains Faulted SG Full of Water for Fission Product Scrubbing	This action is proceduralized, is based on appropriate and clear cues, is simple to perform, and the procedure includes a step that validates performance of the action. While the action is relatively reliable, it is influenced by the high stress of the scenario, which results in the HEP being dominated by a large execution failure term associated with a simple level adjustment action. No procedural changes have been identified that would significantly improve the assessed reliability of the action. Over 80% of the contributors including this action also include the joint HEP 1RX-JHEP28-HOADA. This event represents the dependent failure combination of performing RCS cooldown in time to prevent SG overfill (stuck open PORV) followed by failure to cool the RCS down in time to terminate break flow before the RWST is depleted. These events lead directly to core damage. Because of the operator dependence issues in the scenarios including this event, SAMAs requiring manual action would provide limited benefit. A potential means of mitigating these scenarios would be to provide an automated RWST makeup system to ensure injection can be maintained to the RCS for an indefinite period. A source of boration is assumed to be required to prevent re-criticality, which could occur in some conditions if un-borated water is used for RCS makeup (SAMA 14).

Table F.5-2a
Braidwood LERF Importance List Review

Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
1AP-BOTHSAT-TRMM	6.25E-03	1.056	BOTH U1 SAT OOS FOR TM - 141 PWR VIA 241; 142 PWR VIA 242; 156 - 159 ON UAT	Addressed in the Level 1 importance list.
%FL1WSM3A0HVACT1	3.85E-05	1.053	UNIT 1 MAJOR FLOOD (>3,700GPM) FROM NORMAL SERVICE WATER INTO AUX BLDG - HVAC 45	This event is included in single cutset which is a normal service water flooding scenario in the Aux Building with failure to provide alternate lube oil cooling to the charging pumps. Including logic to trip the WS pumps on high flow conditions is a potential means of terminating the WS flood before it damages critical equipment (SAMA 16). For cases in which aligning alternate cooling to the charging pump fails, the PDP could be replaced with a self-cooled high pressure injection pump with the capability to auto start on loss of charging flow (SAMA 2). Floods that flow into the Aux Building impact the SX pump rooms via ductwork from the Aux Building drain sump room. Altering the ductwork to eliminate communication between the rooms would help extend the time that is available to mitigate Aux Building flooding events (SAMA 10).
0SX-XTIE-D-HMVRA	3.50E-01	1.052	RECOV OF LOSS OF SX SEAL LOCA (COND PROB OF 0SX-XTIE-D-HMVRA + 0.21 SEAL FAIL)	Addressed in the Level 1 importance list.

Table F.5-2a
Braidwood LERF Importance List Review

Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
1CS001A-----MVOO	1.53E-03	1.047	CS PUMP RWST SUCTION MOV CS001A FAILS TO CLOSE	This event represents a containment isolation failure due to a valve failure. The failure results in an open path between the RWST and the containment sump (from the sump through _SI8811A, _CS009A, and _CS001A to the RWST). The containment isolation assessment does not credit the additional isolation tasks that would close the relevant release pathway (by closing _SI8811A) that are performed in the SACRG-1 procedure. If this action were credited, these contributors would be reduced. No additional procedural changes are considered to be required. The scenarios leading to the containment isolation failures include the same contributors reviewed in the Level 1 importance list (e.g., %SXIE 40%, %RC-SLOC1-N-PSIE 20%, %CCIE 10%, %FL1FPM3A0----T1 8%) and the same SAMAs are applicable. No additional SAMAs are suggested.

Table F.5-2a
Braidwood LERF Importance List Review

Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
1CS001B-----MVOO	1.53E-03	1.047	CS PUMP RWST SUCTION MOV CS001B FAILS TO CLOSE	This event represents a containment isolation failure due to a valve failure. The failure results in an open path between the RWST and the containment sump (from the sump through _SI8811B, _CS009B, and _CS001B to the RWST). The containment isolation assessment does not credit the additional isolation tasks that would close the relevant release pathway (by closing _SI8811B) that are performed in the SACRG-1 procedure. If this action were credited, these contributors would be reduced. No additional procedural changes are considered to be required. The scenarios leading to the containment isolation failures include the same contributors reviewed in the Level 1 importance list (e.g., %SXIE 40%, %RC-SLOC1-N-PSIE 20%, %CCIE 10%, %FL1FPM3A0----T1 8%) and the same SAMAs are applicable. No additional SAMAs are suggested.
1RX-JHEP28-HOADA	3.30E-04	1.045	JOINT HEP FOR 1RC-DS-SGTRHDVOA AND 1RC-LCD----HSYOA	Addressed in the Level 1 importance list.
1SX01PB-----PMFRIE	3.20E-02	1.042	FAILURE OF PUMP 1B TO RUN RANDOMLY	Addressed in the Level 1 importance list.
1FP-PRI-7F-HMVRA	4.50E-01	1.039	RECOV OF LOSS OF SX SEAL LOCA (1FP-PRI-7D-HMVRA + 0.21 + 0.1 FP BREAK LOCATION)	Addressed in the Level 1 importance list.

Table F.5-2a
Braidwood LERF Importance List Review

Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
%APIE	9.60E-01	1.038	INDICATOR FOR AP INITIATING EVENT	Addressed in the Level 1 importance list.
1CV-ALL----HPMOA	1.00E-02	1.035	OPERATORS FAIL TO ESTABLISH COOL SUCTION SOURCE FOR CHARGING PUMP	Addressed in the Level 1 importance list.
1CICS001AB-HMVOA	1.10E-03	1.033	OPERATORS FAIL TO CLOSE RWST SUCTION MOV UPON SWITCH TO RECIRC	This event represents a containment isolation failure due to an operator error related to the failure to close the path between the RWST and the containment sump. The failure results in an open path between the RWST and the containment sump (from the sump through _SI8811A/B, _CS009A/B, and _CS001A/B to the RWST). The containment isolation assessment does not credit the additional isolation tasks that would close the relevant release pathway (by closing _SI8811A/B) that are performed in the SACRG-1 procedure. If this action were credited, these contributors would be reduced. No additional procedural changes are considered to be required. The scenarios leading to the containment isolation failures include the same contributors reviewed in the Level 1 importance list (e.g., %SXIE 40%, %RC-SLOC1-N-PSIE 20%, %CCIE 10%, %FL1FPM3A0----T1 8%) and the same SAMAs are applicable. No additional SAMAs are suggested.

Table F.5-2a
Braidwood LERF Importance List Review

Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
SEAL-U1-TRANS	2.10E-01	1.033	UNIT 1 SEAL LOCA OCCURRED - NON-LOOP SEQUENCES	Addressed in the Level 1 importance list.
%CCIE	9.60E-01	1.033	INDICATOR FOR CC INITIATING EVENT	Addressed in the Level 1 importance list.
1AP142------BSLPIE	2.21E-03	1.033	BUS 142 FAILS	Addressed in the Level 1 importance list.
FLMITIG-M3-T1-FP	6.94E-03	1.029		Addressed in the Level 1 importance list.
1AF-XTIE--EHXVOA	1.00E+00	1.028	OPERATORS FAIL TO EXECUTE AF CROSSTIE FROM OPPOSITE UNIT	Addressed in the Level 1 importance list.
%FL1FPM3A0----T1	7.58E-04	1.027	UNIT 1 MAJOR FLOOD (>3,700GPM) FROM FIRE PROTECTION INTO AUX BLDG - COMMON AREA	Addressed in the Level 1 importance list.
%FL1WSM3A0----T1	4.23E-04	1.022	UNIT 1 MAJOR FLOOD (>3,700GPM) FROM NORMAL SERVICE WATER INTO AUX BLDG - COMMON	Addressed in the Level 1 importance list.

Table F.5-2a
Braidwood LERF Importance List Review

Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
1L2-CNT-VF-CFE4	1.00E-03	1.021	Early Cont Failure due to Direct Containment Heating, Hydrogen Burn, or Stm Expl	Over 99% of the contributors including this event are either small LOCAs or RCP seal LOCAs with AFW available. The early containment failure mechanisms include direct containment heating (DCH), hydrogen burn, and ex-vessel steam explosion. DCH is included because in the scenarios where AFW is available (all cases with event 1L2-CNT-VF-CFE4), RCS pressure is assumed to be reduced to the point where ISGTR is avoided, but not below 200 psig where DCH could be avoided. The SARCG-1 procedure would direct depressurization, but this is not credited in the Level 2 model. Even if depressurization were credited and DCH could be avoided, the early containment failure probability would remain the same for the model as all early containment failure modes are assigned the same failure probability for Braidwood (based on the WCAP guidance). The most effective means of addressing the risk related to this event is to prevent core damage. The contributors are mainly seal LOCAs (72%). For cases in which aligning alternate cooling to the charging pump fails, the PDP could be replaced with a self-cooled high pressure injection pump with the capability to auto start on loss of charging flow (SAMA 2). Installation of "no leak" RCP seals is another option (SAMA 4).

Table F.5-2a
Braidwood LERF Importance List Review

Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
0AP-DLOOP-GT	2.40E-03	1.021	CONDITIONAL PROBABILITY OF DLOOP GIVEN GENERAL TRANSIENT	Addressed in the Level 1 importance list.
1AF01PB-----PDMM	1.05E-02	1.017	AF DIESEL-DRIVEN PUMP 1AF01PB UNAVAILABLE DUE TO MAINTENANCE	Addressed in the Level 1 importance list.
1FW-FRH1---HSGOA	1.10E-03	1.017	OPERATORS FAIL RECOGNIZE THE CUE TO SECONDARY COOLING	Addressed in the Level 1 importance list.
%FW-GTR-1---HWIE	7.30E-01	1.017	GENERAL TRANSIENT INITIATING EVENT	Addressed in the Level 1 importance list.
%DC-LODC111-BSIE	5.37E-04	1.016	LOSS OF DC BUS 111 INITIATING EVENT	Addressed in the Level 1 importance list.
0SX-ALL----CSRPGIE	1.57E-05	1.015	SX STRAINERS - PLUGGED DUE TO CCF (4/4)	Addressed in the Level 1 importance list.
%RC-SGTR1-A-HXIE	8.41E-04	1.015	STEAM GENERATOR TUBE RUPTURE IN S/G 1A	Addressed in the Level 1 importance list.
%RC-SGTR1-B-HXIE	8.41E-04	1.015	STEAM GENERATOR TUBE RUPTURE IN S/G 1B	Addressed in the Level 1 importance list.
%RC-SGTR1-C-HXIE	8.41E-04	1.015	STEAM GENERATOR TUBE RUPTURE IN S/G 1C	Addressed in the Level 1 importance list.
%RC-SGTR1-D-HXIE	8.41E-04	1.015	STEAM GENERATOR TUBE RUPTURE IN S/G 1D	Addressed in the Level 1 importance list.

Table F.5-2a
Braidwood LERF Importance List Review

Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
%RCP-HX-RUPT--IE	1.22E-03	1.014	FREQUENCY OF RCP HEAT EXCHANGER RUPTURE	This event represents in ISLOCA caused by failure of the RCP Thermal Barrier HX (tubes within the RCP rupture) and failure to isolate the component cooling return lines that can transport RCS inventory outside containment. The isolation failures include both a valve failure for the automatic isolation and failure of the manual backup isolation action. Additional manual actions to mitigate the event are likely to provide limited benefit due to dependence issues. A potential means of mitigating this event would be to install the same isolation logic used on valve _CC685 on valve_CC9438 (SAMA 22).
%RC-MLOC1---PMIE	3.99E-04	1.014	MEDIUM LOCA INITIATING EVENT	Addressed in the Level 1 importance list.
0AP-DLOOP-SC	6.70E-01	1.014	FRACTION OF CONDITIONAL LOOPS THAT ARE SWITCHYARD-CENTERED	Addressed in the Level 1 importance list.

Table F.5-2a
Braidwood LERF Importance List Review

Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
1CC9519----HXVOA	1.00E-02	1.013	OPERATOR ACTION TO CLOSE MANUAL VALVE 1CC9519	This action is tied to the ISLOCA initiating event %RCP-HX-RUPT--IE. Currently, this action is a screening value that represents failure to manually isolate the flow in the CC system coming from the thermal barrier HX break and details related to this action are limited. The isolation failures include both a valve failure for the automatic isolation and failure of the manual backup isolation action. Additional manual actions to mitigate the event are likely to provide limited benefit due to dependence issues. A potential means of mitigating this event would be to install the same isolation logic used on valve _CC685 on valve_CC9438 (SAMA 22).
1CC685------MVOO	1.06E-03	1.013	MOV 1CC685 - FAILS TO CLOSE	This event represents failure to close of the RCP Thermal Barrier Cooling return line isolation valve. The event is tied to the ISLOCA initiating event %RCP-HX-RUPT--IE. The isolation failures include both a valve failure for the automatic isolation and failure of the manual backup isolation action. Additional manual actions to mitigate the event are likely to provide limited benefit due to dependence issues. A potential means of mitigating this event would be to install the same isolation logic used on valve _CC685 on valve_CC9438 (SAMA 22).
1RH-SP-X---HPMOA	7.30E-04	1.012	OPERATORS FAIL TO STOP RH PUMPS	Addressed in the Level 1 importance list.

Table F.5-2a
Braidwood LERF Importance List Review

Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
1AF01PA-----PMMM	4.31E-03	1.011	AF MOTOR-DRIVEN PUMP 1AF01PA UNAVAILABLE DUE TO MAINTENANCE	Addressed in the Level 1 importance list.
1AF01PA-B--CPMFR	8.20E-05	1.011	AF PUMPS FAIL TO RUN DUE TO CCF (2/2)	Addressed in the Level 1 importance list.
1CC01PA-B--CPMFRIE	4.96E-04	1.01	CCW PUMPS 1CC01PA & 1CC01PB FAIL TO RUN DUE TO CCF (2/4)	Addressed in the Level 1 importance list.
%FW-LMFW1---HWIE	6.88E-02	1.01	TOTAL LOSS OF MAIN FEEDWATER	Addressed in the Level 1 importance list.
1SI-HPR----HSYOA	6.80E-03	1.009	OPERATORS FAIL TO ESTABLISH HIGH PRESSURE RECIRC (SLOW EVENT)	Addressed in the Level 1 importance list.
1RX-JHEP17-HOADA	3.60E-05	1.009	JOINT HEP FOR 1AF01PB-FO-HXVOA AND 1FW-FRH1---HSGOA	Addressed in the Level 1 importance list.

Table F.5-2a
Braidwood LERF Importance List Review

Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
1RX-JHEP64-HOADA	8.70E-03	1.009	JOINT HEP FOR 1AF-STARTFWHPMOA AND 1FW-FRH1---HSGOA	This dependent human failure event represents the failure to start AFW on failure of the auto start function and subsequent failure to diagnose the need to align alt heat removal such as FW restoration, AFW X-tie, or bleed and feed cooling. The independent action to align alternate heat removal is relatively reliable, has an alarmed cue, and clear procedure guidance. However, the dependent action chain begins with AFW start, which has a short available time for response and a relatively high HEP that drives the JHEP. Given the longer time frame available for starting Feed and Bleed, the importance of the action may be conservative. However, the AMSAC low level logic could be used to provide a backup start signal for AFW to mitigate these scenarios (SAMA 17).
1CV-ALL-D--HPMRA	3.60E-01	1.008	RECOV OF LOSS OF SX SEAL LOCA (COND PROB OF 1CV-ALL-D-HPMRA + 0.21 SEAL FAIL)	Addressed in the Level 1 importance list.

Table F.5-2a
Braidwood LERF Importance List Review

Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
1L2-CNT-VF-CFE2	1.00E-03	1.008	Early Cont Failure due to Hydrogen Burn	The scenarios that include this event are essentially all cases in which the operators successfully depressurize the RCS before TI-SGTR and reactor pressure vessel (RPV) breach. The low pressure conditions preclude all early containment failure modes but hydrogen explosions. While this failure mode is considered to be highly unlikely for the Braidwood containment design, the event is included in the Level 2 model as a potentially conservative representation of the evolution. A potential means of mitigating early containment failure due to hydrogen detonations would be to install a passive hydrogen ignition system (SAMA 23).
1RY-PORV---HPVOA	2.50E-02	1.007	OPERATORS FAIL TO PREVENT WATER CHALLENGE TO PZR PORVs	Addressed in the Level 1 importance list.
%CD-LCND1---HWIE	5.44E-02	1.007	LOSS OF CONDENSER HEAT SINK	Addressed in the Level 1 importance list.
1SX01AB-----HXFFIE	5.65E-03	1.007	SX PUMP 1B OIL COOLER FAILS DURING OPERATION	Addressed in the Level 1 importance list.
1CC01A------HXFFIE	5.34E-03	1.006	CCW HTX 1CC01A - LOSS OF FUNCTION	Addressed in the Level 1 importance list.
1RX-JHEP32-HOADA	4.90E-04	1.006	JOINT HEP FOR 0CC-HTX0---HHXOA AND 1CV-ALL----HPMOA	Addressed in the Level 1 importance list.

Table F.5-2a
Braidwood LERF Importance List Review

Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
1RC-DS-SGTRHDVOA	6.30E-03	1.006	OPERATORS FAIL TO COOLDOWN THE RCS	Over 50% of the contributors including this action are tied to the failure to perform the action to throttle the _SX007 valves. While the action is reliable, review of the HRA indicates that the dominant contributor is the execution component. Currently, the procedures do not explicitly direct the operators to independently check the throttling action, which results in a relatively large failure probability for a simple execution. While it is not unreasonable to expect the RHR/CC temperatures would be closely monitored in the MCR, updating the procedures to explicitly direct an independent check of the valve throttling action would improve the assessed reliability of the action (SAMA 6). For the 1RC-DS-SGTRHDVOA itself, the execution component is also dominant, but there is a general recovery credit taken. Adding a specific procedure check for this action would yield limited benefit due to dependence factors associated with the check. In addition, a procedure change would provide only academic value given that the cooldown process is highly visible and an execution failure is unlikely to be missed. No additional SAMAs suggested.
1FW02P------PMMM	1.58E-02	1.006	MFW MD START UP PUMP FW02P UNAVAILABLE DUE TO MAINTENANCE	Addressed in the Level 1 importance list.

Table F.5-2a
Braidwood LERF Importance List Review

Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
1AF01PB-----PDFS	2.71E-03	1.006	DIESEL-DRIVEN PUMP 1AF01PB RANDOM FAILURE TO START	Addressed in the Level 1 importance list.
1RX-JHEP47-HOADA	3.30E-04	1.005	JOINT HEP FOR 1RC-PUMPS--HPMOA AND 0SX005-----HMVOA AND 1FP-PRI-7X-HMVOA	Addressed in the Level 1 importance list.
1RX-JHEP48-HOADA	3.30E-04	1.005	JOINT HEP FOR 1RC-PUMPS--HPMOA AND 0SX005-----HMVOA AND 1CV-ALL----HPMOA	Addressed in the Level 1 importance list.
1AF01PA-----PMFS	1.23E-03	1.005	MOTOR-DRIVEN PUMP 1AF01PA RANDOM FAILURE TO START	About 70% of the contributors including this event result in PI-SGTR. A large majority of those cases include the failure to restore FW to operation after AFW failure. If FW was restored, RCS pressure would be reduced to avoid the PI-SGTR event. A potential means of mitigating the PI-SGTR scenarios would be to modify the Startup FW pump to auto start and align on low SG level (using the AMSAC SG level signal) (SAMA 5). For the remaining contributors, which include containment isolation failures, SAMA 5 is also a means of avoiding core damage by restoring secondary side heat removal.

Table F.5-2a
Braidwood LERF Importance List Review

Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
1AP131X1M2--CBOO	2.50E-03	1.005	FEED BREAKER 131X1M2 FROM MCC 131X1 FAIL TO CLOSE	These failures, in combination with specific breaker failures, result in the loss of power to the Safety Injection minimum flow valves. For cases in which recirculation mode initiates successfully but subsequently fails due RHR pump failures, loss of power to the _SI8813, _SI8814, and SI8820 valves can result in a containment isolation failure. However, the current containment isolation analysis does not take credit for the additional isolation tasks that would close the relevant release pathway (by closing _SI8811A/B) that are performed in the SACRG-1 procedure. If this action were credited, these contributors would be reduced. No additional procedural changes are considered to be required. The contributors that lead to core damage are those that have been treated in the level 1 importance, including the failure to align alternate cooling or a cool suction source for the charging pumps. Over 75% of the contributors are RCS Seal LOCAs, which could be addressed by providing a self-cooled, auto start seal injection pump (SAMA 2) or by installing "no leak" RCP seals (SAMA 4).
1RX-JHEP22-HOADA	1.40E-03	1.005	JOINT HEP FOR 0SX-XTIE---HMVOA AND (1FP-PRI-7X-HMVOA OR 1CV-ALL----HPMOA)	Addressed in the Level 1 importance list.

Table F.5-2a
Braidwood LERF Importance List Review

Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
1CC01PAB2A-CPMFRIE	2.37E-04	1.005	CCW PUMPS 1CC01PA/1CC01PB/2CC01PA FAIL TO RUN DUE TO CCF (3/4)	Addressed in the Level 1 importance list.
1CC01PAB2B-CPMFRIE	2.37E-04	1.005	CCW PUMPS 1CC01PA/1CC01PB/2CC01PB FAIL TO RUN DUE TO CCF (3/4)	Addressed in the Level 1 importance list.
1FW01PA-----PMMM	1.58E-02	1.005	MAINTENANCE UNAVAILABILITY OF PUMP FW01PA	Over 75% of the contributors including this event result in PI-SGTR. Over 94% are initiated by common cause failure of all SX pumps followed by failure of the MFW system to provide heat removal. Because many of those failures include unavailability of the startup feedwater pump, SAMA 2 is not an option. Providing an alternate, diesel driven SX pump is a potential means of reducing the risk of this scenario (SAMA 1). A potentially more cost effective solution would be to modify the AFW pumps to be self-cooled in conjunction with the replacement of the PDP with a self-cooled, auto start pump that would protect the RCP seals (SAMA 13).
1RH01PB-----PMMM	9.80E-03	1.005	RH PUMP 1RH01PB UNAVAILABLE DUE TO MAINTENANCE	Addressed in the Level 1 importance list.

Table F.5-2b
Braidwood LATE Importance List Review

Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
%SXIE	9.60E-01	2.475	INDICATOR FOR SX INITIATING EVENT	Addressed in the Level 1 importance list.
0SX01AB2AB-CPMFRIE	2.16E-04	1.482	FAILURE OF ALL SX PUMPS (1A/1B/2A/2B) TO RUN DUE TO CCF (4/4)	Addressed in the Level 1 importance list.
FLAG-CCHTX0-U2	5.00E-01	1.473	CCW HTX 0 ALIGNED TO UNIT 2	Addressed in the Level 1 importance list.
FLAG-CCHTX0-U1	5.00E-01	1.368	CCW HTX 0 ALIGNED TO UNIT 1	Addressed in the Level 1 importance list.
1RX-JHEP05-HOADA	3.30E-04	1.356	JHEP - 1RC-PUMPS--HPMOA/0SX-XTIE---HMVOA/(1FP-PRI-7X-HMVOA OR 1CV-ALL----HPMOA)	Addressed in the Level 1 importance list.
0SX-XTIE-D-HMVRA	3.50E-01	1.305	RECOV OF LOSS OF SX SEAL LOCA (COND PROB OF 0SX-XTIE-D-HMVRA + 0.21 SEAL FAIL)	Addressed in the Level 1 importance list.
1SX01PB-----PMFRIE	3.20E-02	1.23	FAILURE OF PUMP 1B TO RUN RANDOMLY	Addressed in the Level 1 importance list.
1FP-PRI-7F-HMVRA	4.50E-01	1.189	RECOV OF LOSS OF SX SEAL LOCA (1FP-PRI-7D-HMVRA + 0.21 + 0.1 FP BREAK LOCATION)	Addressed in the Level 1 importance list.
1FW-FWR---EHSYOA	1.40E-02	1.176	OPERATORS FAIL TO EXECUTE FW RESTORATION	Addressed in the Level 1 importance list.
FLMITIG-M3-T1-FP	6.94E-03	1.134		Addressed in the Level 1 importance list.

Table F.5-2b
Braidwood LATE Importance List Review

Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
%FL1FPM3A0----T1	7.58E-04	1.127	UNIT 1 MAJOR FLOOD (>3,700GPM) FROM FIRE PROTECTION INTO AUX BLDG - COMMON AREA	Addressed in the Level 1 importance list.
%APIE	9.60E-01	1.11	INDICATOR FOR AP INITIATING EVENT	Addressed in the Level 1 importance list.
1AP142------BSLPIE	2.21E-03	1.094	BUS 142 FAILS	Addressed in the Level 1 importance list.
1AP-BOTHSAT-TRMM	6.25E-03	1.072	BOTH U1 SAT OOS FOR TM - 141 PWR VIA 241; 142 PWR VIA 242; 156 - 159 ON UAT	Addressed in the Level 1 importance list.
1CV-ALL----HPMOA	1.00E-02	1.048	OPERATORS FAIL TO ESTABLISH COOL SUCTION SOURCE FOR CHARGING PUMP	Addressed in the Level 1 importance list.
1FP-PRI-7D-HMVRA	3.50E-01	1.048	RECOV OF LOSS OF SX SEAL LOCA (COND PROB OF 1FP-PRI-7D-HMVRA + 0.21 SEAL FAIL)	Addressed in the Level 1 importance list.
1CV-ALL-D--HPMRA	3.60E-01	1.039	RECOV OF LOSS OF SX SEAL LOCA (COND PROB OF 1CV-ALL-D-HPMRA + 0.21 SEAL FAIL)	Addressed in the Level 1 importance list.
1SX01AB-----HXFFIE	5.65E-03	1.034	SX PUMP 1B OIL COOLER FAILS DURING OPERATION	Addressed in the Level 1 importance list.
0AP-DLOOP-GT	2.40E-03	1.032	CONDITIONAL PROBABILITY OF DLOOP GIVEN GENERAL TRANSIENT	Addressed in the Level 1 importance list.

Table F.5-2b
Braidwood LATE Importance List Review

Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
1L2-CNT-VF-BMMTW	5.00E-02	1.031	Probability of BMMT with water in the cavity	These scenarios are those in which core damage has occurred, early containment failure has not occurred, the RCFS have provided containment heat removal, and containment spray has functioned to transfer water to the containment floor. Changes such as flooded rubble beds and core catchers are not suggested since they have been analyzed many times and determined not to be cost beneficial. A potential means of reducing these types of releases would be to install a reactor cavity flooding mechanism that could rapidly transfer water to the cavity at a depth that would provide adequate cooling for the lower part of the RPV (SAMA 24).
FLMITIG-M3-T1-WS	3.90E-03	1.029		Addressed in the Level 1 importance list.
%FL1WSM3A0----T1	4.23E-04	1.029	UNIT 1 MAJOR FLOOD (>3,700GPM) FROM NORMAL SERVICE WATER INTO AUX BLDG - COMMON	Addressed in the Level 1 importance list.
1RX-JHEP22-HOADA	1.40E-03	1.026	JOINT HEP FOR 0SX-XTIE---HMVOA AND (1FP-PRI-7X-HMVOA OR 1CV-ALL----HPMOA)	Addressed in the Level 1 importance list.
%FL1SX-MA0----T2	1.65E-04	1.025	UNIT 1 MAJOR FLOOD (>2000GPM) FROM SX INTO AUX BLDG - COMMON AREA	Addressed in the Level 1 importance list.
0SX-ALL----CSRPGIE	1.57E-05	1.024	SX STRAINERS - PLUGGED DUE TO CCF (4/4)	Addressed in the Level 1 importance list.
0AP-DLOOP-SC	6.70E-01	1.022	FRACTION OF CONDITIONAL LOOPS THAT ARE SWITCHYARD-CENTERED	Addressed in the Level 1 importance list.

Table F.5-2b
Braidwood LATE Importance List Review

Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
%SP-BB-A-SXPRB-1	1.21E-03	1.022	GLOBAL SPRAY SCENARIO UNIT 1 BYRON AND BRAIDWOOD IN AUX BLDG - SX PUMP ROOM B	Addressed in the Level 1 importance list.
FLMITIG--G-T1-FP	2.23E-04	1.02		Addressed in the Level 1 importance list.
%FL1FP-GA0----T1	3.99E-03	1.019	UNIT 1 GENERAL FLOOD (100-2000GPM) FROM FIRE PROTECTION INTO AUX BLDG - COMMON A	Addressed in the Level 1 importance list.
FLMITIG-M2-T1-FP	2.19E-03	1.019		Addressed in the Level 1 importance list.
1FP-PRI-7X-HMVOA	4.60E-03	1.018	OPERATORS FAIL TO ALIGN FP SEAL COOLING - SX NON-PIPE FAILURE INITIATOR	Addressed in the Level 1 importance list.
%FL1FPM2A0----T1	3.77E-04	1.018	UNIT 1 MAJOR FLOOD M2 (3,700GPM) FROM FIRE PROTECTION INTO AUX BLDG - COMMON ARE	Addressed in the Level 1 importance list.
1SX01PA-----PMMM	1.05E-02	1.018	SX PUMP 1A UNAVAILABLE DUE TO MAINTENANCE	Addressed in the Level 1 importance list.
1RX-JHEP47-HOADA	3.30E-04	1.017	JOINT HEP FOR 1RC-PUMPS--HPMOA AND 0SX005-----HMVOA AND 1FP-PRI-7X-HMVOA	Addressed in the Level 1 importance list.
1RX-JHEP48-HOADA	3.30E-04	1.017	JOINT HEP FOR 1RC-PUMPS--HPMOA AND 0SX005-----HMVOA AND 1CV-ALL----HPMOA	Addressed in the Level 1 importance list.
FLMITIG--M-T2-SX	2.09E-03	1.016		Addressed in the Level 1 importance list.

Table F.5-2b
Braidwood LATE Importance List Review

Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
0SX007-ES13HMVOA	3.40E-03	1.016	OPERATORS FAIL TO LOCALLY THROTTLE SX007 TO CC HXS	Addressed in the Level 1 importance list.
%RC-SLOC1-N-PSIE	1.40E-03	1.015	SMALL LOCA INITIATING EVENT (NON-ISOLABLE)	Addressed in the Level 1 importance list.
1SX01FB-2---SRPGIE	2.51E-03	1.015	SX STRAINER 1SX01FB-2 PLUGGED	Addressed in the Level 1 importance list.
1AF-XTIE--EHXVOA	1.00E+00	1.013	OPERATORS FAIL TO EXECUTE AF CROSSTIE FROM OPPOSITE UNIT	Addressed in the Level 1 importance list.
1FW-FRH1---HSGOA	1.10E-03	1.012	OPERATORS FAIL RECOGNIZE THE CUE TO SECONDARY COOLING	Addressed in the Level 1 importance list.
%SY-WRDLOOP-DLIE	2.86E-03	1.009	DUAL UNIT WEATHER-RELATED LOSS OF OFFSITE POWER (SUSTAINED)	About 95% of these contributors are SBO evolutions with seal LOCAs. Implementation of the DMS is a means of addressing these scenarios (SAMA 11).
1FW02P------PMMM	1.58E-02	1.008	MFW MD START UP PUMP FW02P UNAVAILABLE DUE TO MAINTENANCE	Addressed in the Level 1 importance list.
SEAL-U1-TRANS	2.10E-01	1.008	UNIT 1 SEAL LOCA OCCURRED - NON-LOOP SEQUENCES	Addressed in the Level 1 importance list.
%CCIE	9.60E-01	1.008	INDICATOR FOR CC INITIATING EVENT	Addressed in the Level 1 importance list.

Table F.5-2b
Braidwood LATE Importance List Review

Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
FLMITIG-FPCVCOOL	3.90E-03	1.007		This event represents the failure to align fire protection to alternate charging pump lube oil cooling for general flooding in the Auxiliary Building, many of which are SX system flood events. For these cases, the PDP could be replaced with a self-cooled high pressure injection pump with the capability to auto start on loss of charging flow (SAMA 2). An alternate means of preventing a seal LOCA would be to install "no leak" seals (SAMA 4).
0AP-DLOOP-PC	2.20E-01	1.007	FRACTION OF CONDITIONAL LOOPS THAT ARE PLANT-CENTERED	Over 80% of the contributors including this event are loss of SX event with consequential LOOP, which ultimately fails all heat removal capability. For these cases, RCP seal protection can be pursued, but FW restoration is not available and an alternate form of heat removal is required. Replacing the PDP with a self-cooled high pressure injection pump with auto start capability would provide a means of maintaining RCP seal injection. For heat removal, the AFW output flow can be routed to the lube oil coolers to eliminate the SX cooling dependence (SAMA 13). For the SBO contributors, implementation of the DMS would provide a means of maintaining heat removal and inventory control indefinitely (SAMA 11).

Table F.5-2b
Braidwood LATE Importance List Review

Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
1SX01A-1B--CPMFRIE	2.94E-04	1.007	FAILURE OF SX PUMPS 1A & 1B TO RUN DUE TO COMMON CAUSE	Over 95% of the contribution for this event comes from its combination with 1RX-JHEP22-HOADA or some combination of the events in this dependent failure combination. 1RX-JHEP22-HOADA represents the failure to align the SX cross-tie and either the failure to align a cool suction source to the charging pumps or to align fire protection to the charging pump lube oil coolers. For cases in which aligning alternate cooling to the charging pump fails, the PDP could be replaced with a self-cooled high pressure injection pump with the capability to auto start on loss of charging flow (SAMA 2). A diesel driven SX pump could be used to mitigate CCF failures of the SX pumps. To maximize benefit, controls would have to be included in the MCR (SAMA 1).
1RC-UBR2---2WRUB	1.52E-01	1.007	CORE UNCOVERY BEFORE POWER RECOVERY AFTER WEATHER-RELATED LOOP OR DLOOP - UBR2	Over 99% of the contributors including this event are SBO scenarios with seal LOCAs. Implementation of the DMS would provide a means of maintaining heat removal and inventory control indefinitely (SAMA 11).
1AP141------BSLPIE	2.21E-03	1.007	BUS 141 FAILS	Addressed in the Level 1 importance list.
1SX016A027A-MVMM	4.14E-03	1.006	SX PUMP A MIN FLOW PATH VIA SX 16A\ 27A (RCFC 1A\1C) IS ISOLATED	This event (maintenance unavailability) fails 2 out of 4 RCFCs and is combined with divisional SX or power failures that fail the remaining 2 RCFCs, which results in containment overpressure. Almost all events include RCP seal LOCAs due to loss of SX and failure to align alternate charging pump cooling. The failure of the "A" SX pump is due to a logical interlock that prevents manual start of the standby SX pump when the corresponding RCFC inlet or outlet valves are closed. An auto start signal bypasses this logic. The SAMA to auto start the standby SX pump on low flow would mitigate this event (SAMA 3).

Table F.5-2b
Braidwood LATE Importance List Review

Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
1FW01PA-----PMMM	1.58E-02	1.006	MAINTENANCE UNAVAILABILITY OF PUMP FW01PA	Over 97% of the contributors that include this event are linked to the loss of SX initiator (over 90% is due to loss of all 4 pumps). Most of the cutsets include some failure of the startup feedwater pump, which eliminates the remaining heat removal mechanism for the total SX failure event. Replacing the PDP with a self-cooled high pressure injection pump with auto start capability would provide a means of maintaining RCP seal injection. For heat removal, the AFW output flow can be routed to the lube oil coolers to eliminate the SX cooling dependence (SAMA 13).
0SX01AB2AB-CPMFR	5.90E-07	1.006	FAILURE OF ALL SX PUMPS (1A/1B/2A/2B) TO RUN DUE TO CCF (4/4)	Addressed in the Level 1 importance list.
1RX-JHEP02-HOADA	6.60E-04	1.005	JOINT HEP FOR 1RC-PUMPS--HPMOA AND 1CV-ALL----HPMOA	The contribution from this event is almost exclusively linked to the failure to manually start the standby SX pump given failure of the running pump. It is combined with the failure to align a cool suction source to the charging pumps after loss of SX. To mitigate these events, the PDP could be replaced with a self-cooled high pressure injection pump with the capability to auto start on loss of charging flow (SAMA 2). Alternatively, automating the start of the standby SX pump on failure of the running pump is a potential solution (SAMA 3).
1RX-JHEP10-HOADA	4.70E-05	1.005	JOINT HEP FOR 1RC-PUMPS--HPMOA AND 0SX-XTIE---HMVOA AND 1AF-AF005--HAVOA	The contribution from this event is almost exclusively linked to the failure to manually start the standby SX pump given failure of the running pump due to bus failure. It is also combined with the failure to align the AFW and SX cross-ties. Automating the start of the standby SX pump on failure of the running pump is a potential means of mitigating these scenarios (SAMA 3).

Table F.5-2b
Braidwood LATE Importance List Review

Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
1FWTRAIN-2-HOEXM	1.00E-02	1.005	1FW02P PUMP TRAIN RESTORATION FAILURE POST T/M	Over 97% of the contributors that include this event are linked to the loss of SX initiator (over 90% is due to loss of all 4 pumps). Most of the cutsets include some failure of the motor driven feedwater pump, which eliminates the remaining heat removal mechanism for the total SX failure event. Replacing the PDP with a self-cooled high pressure injection pump with auto start capability would provide a means of maintaining RCP seal injection. For heat removal, the AFW output flow can be routed to the lube oil coolers to eliminate the SX cooling dependence (SAMA 13).
1AP1415X25XCHBCOIE	4.56E-05	1.005	4KV FEED BREAKER 1415X AND 1425X OPEN SPURIOUSLY DUE TO CCF (2/2)	This event represents common cause breaker failures that fail the 4KV to 480V path for critical loads. The top 99.9% of the contributors are RCP seal LOCAs with AFW available that lead to core damage because RHR is unavailable for recirculation (room cooling failure due to power dependencies). Installation of the "no leak" seals would provide a success path for these cases (SAMA 4).
1RX-JHEP13-HOADA	6.50E-04	1.005	JOINT HEP FOR 1RC-PUMPS--HPMOA AND 0SX-XTIE---HMVOA	The contributors including this event are loss of SX events in which the operators fail to manually start the standby SX pump and then fail to align the SX cross-tie. Automating the start of the standby SX pump on failure of the running pump is a potential means of mitigating these scenarios (SAMA 3).

Table F.5-2b
Braidwood LATE Importance List Review

Event Name	Probability	Risk Reduction Worth	Description	Potential SAMAs
FLMITIG-M3-T2-WS	2.14E-04	1.005		This event represents the failure to terminate a flood in the non-essential service water system (>3700 gpm) in the Aux Building before the flood water fails the CV, SI, and CC pumps. Including logic to trip the WS pumps on high flow conditions is a potential means of terminating the WS flood before it damages critical equipment (SAMA 16). Installation of "no leak" RCP seals may provide a means of maintaining RCS inventory for a long period of time while the startup feedwater system provides heat removal (SAMA 4).
%FL1WSM3A0----T2	4.62E-04	1.005	UNIT 1 MAJOR FLOOD (>3,700GPM) FROM NORMAL SERVICE WATER INTO AUX BLDG - COMMON	This event represents a flood in the non-essential service water system (>3700 gpm) in the Aux Building. Nearly all of the contribution comes from a single cutset, which includes the event to mitigate the flood (FLMITIG-M3-T2-WS) before the flood water fails the CV, SI, and CC pumps. Including logic to trip the WS pumps on high flow conditions is a potential means of terminating the WS flood before it damages critical equipment (SAMA 16). Installation of "no leak" RCP seals may provide a means of maintaining RCS inventory for a long period of time while the startup feedwater system provides heat removal (SAMA 4).

Table F.5-3
Braidwood Phase 1 SAMA List Summary

SAMA Number	SAMA Title	SAMA Description	Source	Cost Estimate	Phase 1 Baseline Disposition
1	Diesel Driven SX Pump	In order to mitigate CCF failure of the SX pumps, a diesel driven pump could be installed in a flood safe location with suction from the WS forebay that includes a suction strainer of an alternate design that is accessible for manual cleaning (in place of the pump discharge strainers). Auto start capability would be required to increase the benefit of the SAMA, but water level interlocks for critical rooms (e.g., SX pump rooms, Aux Building sump) may be required to prevent auto start in SX flooding evolutions.	Braidwood Level 1 Importance Review	Due to space and exhaust issues, a diesel driven system will require an additional structure to house the pump and diesel engine combination. Limerick estimated the cost of a diesel driven suppression pool cooling system (housed in a dedicated building) to be $25,600,000 in 1989 (PECO 1989). The Limerick enhancement is considered to be similar in scope to this SAMA and it is used as the basis for the cost estimate. Using the CPI to scale to cost to 2011 dollars, the result is about $46,431,000 (224.9/124.0 *$25,600,000) (UDSL 2012).	The implementation cost for this SAMA is greater than the MACR, but because of the small margin by which it exceeds the MACR, it SAMA has been retained for Phase 2 analysis.
2	Replace the Positive Displacement Pump with a Self-Cooled, Auto Start Pump	Loss of SX requires swap of the charging pump suction source to the RWST as well as alignment of an alternate lube oil cooling source to maintain RCP seal injection. Replacing the positive displacement pump with a self-cooled pump with the capability to auto start on loss of charging and SX flow would provide a means of seal cooling on loss of the normal pumps. Providing an automatic transfer switch to allow power from either division would enhance the SAMA's capability.	Braidwood Level 1 Importance Review	Exelon estimates the cost of this SAMA to be $5,751,110.	As the implementation cost is less than the MACR, this SAMA has been retained for Phase 2 analysis.

Table F.5-3
Braidwood Phase 1 SAMA List Summary

SAMA Number	SAMA Title	SAMA Description	Source	Cost Estimate	Phase 1 Baseline Disposition
3	Auto Start of Standby SX Pump	Automating the start of the standby SX pump would help reduce the reliance of operators to maintain cooling to critical loads. Use of flooding interlocks could be used to prevent auto actuation in flooding scenarios.	Braidwood Level 1 Importance Review	Exelon estimates the cost of this SAMA to be $1,130,300.	As the implementation cost is less than the MACR, this SAMA has been retained for Phase 2 analysis.
4	Install "No Leak" RCP Seals	For loss of RCP seal cooling scenarios, a passive means of reducing the probability of an RCP seal LOCA is to replace the existing pump seals with "no leak" seals (e.g., Westinghouse "shield" seals) that are less likely to fail on loss of cooling.	Braidwood Level 1 Importance Review	Exelon estimates the cost of this SAMA to be $12,230,000.	As the implementation cost is less than the MACR, this SAMA has been retained for Phase 2 analysis.
5	Modify the Startup Feedwater Pump to Start Using the AMSAC SG Low-Low-Low Level signal to Mitigate AFW Failure	For accident sequences in which main feedwater has tripped and AFW has failed to start, it is necessary to manually restart the FW system for continued SG makeup. By modifying the startup feedwater pump to auto start and align on low steam generator level, the need for operator intervention after AFW failure is essentially eliminated. Use of the AMSAC low-low-low SG level signal is an additional benefit that mitigates start signal failures.	Braidwood Level 1 Importance Review	Exelon estimates the cost of this SAMA to be $657,200.	As the implementation cost is less than the MACR, this SAMA has been retained for Phase 2 analysis.

Table F.5-3
Braidwood Phase 1 SAMA List Summary

SAMA Number	SAMA Title	SAMA Description	Source	Cost Estimate	Phase 1 Baseline Disposition
6	Enhance Plant Procedures to Explicitly Confirm Adequate _SX007 Throttling	Due to variability in the temperature of the lake that serves as the water source for the Braidwood SX system, the _SX007 valve must be throttled to ensure the heat removal system is adequately balanced after RH initiation. Currently, the procedures do not explicitly require an independent check of the throttling action. Enhancing the procedures to explicitly direct such an independent check would improve the assessed reliability of the throttling action.	Braidwood Level 1 Importance Review	Procedure changes are estimated to cost $100,000 per site.	As the implementation cost is less than the MACR, this SAMA has been retained for Phase 2 analysis.
7	Establish Flow to the RH HX on RH Pump Start	To prevent overheating the RH pumps when they are operating on min-flow without CC cooling to the heat exchangers, procedure EP-0 (and potentially others) could be changed to direct the operators to align CC to the RH HX when the RH pumps start. This precludes the need for the operators to rely on a continuous action statement to protect the RH pumps if secondary side cooling is not established.	Braidwood Level 1 Importance Review	Procedure changes are estimated to cost $100,000 per site.	As the implementation cost is less than the MACR, this SAMA has been retained for Phase 2 analysis.
8	Install Kill Switches for the Fire Protection Pumps in the MCR	Currently, it is not possible to terminate all flow from the fire protection system in the MCR. In the event of a flood caused by a fire protection system break, the availability of controls in the MCR that would allow the operators to shut down the fire protection pumps would increase the likelihood that the flood could be terminated before critical equipment is damaged.	Braidwood Level 1 Importance Review	Exelon estimates the cost of this SAMA to be $338,830.	As the implementation cost is less than the MACR, this SAMA has been retained for Phase 2 analysis.

Table F.5-3
Braidwood Phase 1 SAMA List Summary

SAMA Number	SAMA Title	SAMA Description	Source	Cost Estimate	Phase 1 Baseline Disposition
9	Install Flow Restrictors in Fire Protection Pipes	Large breaks in the fire protection systems are significant contributors to plant risk. Installing flow restrictors in the auxiliary building piping would increase the time available to respond to these flooding events. Locating flow restrictors outside the auxiliary building upstream of valves 0FP209A, 0FP209B, and FP033 would provide adequate protection for auxiliary building floods.	Braidwood Level 1 Importance Review	Exelon estimates the cost of this SAMA to be $349,300.	As the implementation cost is less than the MACR, this SAMA has been retained for Phase 2 analysis.
10	Alter Ductwork Between the Aux Bldg Sump Drain Room and the SX Pump Room	Currently, the ductwork between the Auxiliary Building Sump Drain Room and the SX Pump Rooms provides a flowpath for flood water when the Auxiliary Building Sump Drain Room fills with water (at a depth of about 12 feet). Water then flows through the ductwork to the SX pump room and damages the SX pumps. Eliminating this pathway will increase the time available to mitigate the flooding event by precluding SX pump damage from the flooding event.	Braidwood Level 1 Importance Review	Exelon estimates the cost of this SAMA to be $1,320,300.	As the implementation cost is less than the MACR, this SAMA has been retained for Phase 2 analysis.

Table F.5-3
Braidwood Phase 1 SAMA List Summary

SAMA Number	SAMA Title	SAMA Description	Source	Cost Estimate	Phase 1 Baseline Disposition
11	Implement DMS	The diverse and flexible coping strategies (FLEX) guide identifies different means of addressing required plant functions in extreme accident conditions, but for the SAMA analysis a specific approach, called the Diverse Mitigation System (DMS), is proposed. A portable 480V AC generator is proposed as a means of supporting long term AFW operation by means of maintaining instrumentation and control power for the system by energizing the buses used for the battery chargers. A portable, engine driven SG makeup pump would provide an alternate means of SG makeup, with injection connections available on different divisions. Fire protection should provide both CST makeup and a suction source connection for the portable SG makeup pump. Use of high temperature RCP seals would limit primary system leakage and the positive displacement pump could be replaced by one that could be powered by the portable generator for long term RCS makeup. A means of providing borated makeup to the RWST is also required, which could potentially be performed using the fire protection system and an eductor. Finally, a connection point to an outside source would have to be provided for the containment spray system for long term spray capability in an SBO.	Braidwood Level 1 Importance Review	For this application, the cost is based on a reduced scope of the DMS that accounts only for the alternate 480V AC power source, alternate SG makeup pump, and "no-leak" RCP seals. Ginna estimated the cost of a skid mounted 480V AC generator to be $400,000 (RG&E 2002). An additional $400,000 is assumed for the cost of the portable, engine driven SG makeup pump to address conditions where the AFW pumps are unavailable. This is combined with the cost of SAMA 4 to yield a total of $13,030,000.	As the implementation cost is less than the MACR, this SAMA has been retained for Phase 2 analysis.

Table F.5-3
Braidwood Phase 1 SAMA List Summary

SAMA Number	SAMA Title	SAMA Description	Source	Cost Estimate	Phase 1 Baseline Disposition
12	Modify Practices for SAT Maintenance or Enhance Procedures	For on-line SAT maintenance, a single SAT can provide power to the loads normally supplied by both SATs on a given unit. However, in order to align this configuration, there is a transition period during which both SATs are unable to provide power to any bus. For loss of SX events, this condition is critical because it eliminates the ability to provide power to the Feedwater system for heat removal, which is the only heat removal mechanism available without SX (due to system dependencies). Precluding on-line SAT maintenance is a potential means of reducing this on-line risk. Alternatively, existing Braidwood procedures could be modified to serve as contingency procedures for these maintenance evolutions. Braidwood has procedures to provide power to the buses required to power the Startup Feedwater pump, but they are not clearly linked to address the SAT maintenance scenario. Providing clear contingency procedures to perform the required power alignment could help reduce the risk of these scenarios.	Braidwood Level 1 Importance Review	Exelon plant personnel estimate that moving the SAT maintenance to an outage would require 1 week of additional time each outage at a cost of about $1 million a day. For a two year cycle over 20 years, the total additional time would be 70 days for a total of $70 million.	As the implementation cost is greater than the MACR, this SAMA has screened from further analysis.

Table F.5-3
Braidwood Phase 1 SAMA List Summary

SAMA Number	SAMA Title	SAMA Description	Source	Cost Estimate	Phase 1 Baseline Disposition
13	Alternate AFW Cooling with Seal Protection	For loss of SX events with consequential LOOP, the AFW lube oil coolers are unavailable and the AFW pumps are assumed to fail. The AFW discharge flow could be routed back to the lube oil coolers to provide a self-cooling mechanism that would eliminate the SX dependence. The cooling water return path could potentially be returned to the AFW pump discharge path. For RCP seal protection, replacing the positive displacement pump with a self-cooled pump with the capability to auto start on loss of charging flow and/or high seal injection water temp would provide a success path.	Braidwood Level 1 Importance Review	Ginna estimated the cost of the AFW change to be $200,000 (RG&E 2002). This is used with the cost of SAMA 2 to get a total of $5,951,110 for this SAMA.	As the implementation cost is less than the MACR, this SAMA has been retained for Phase 2 analysis.
14	Automated RWST Makeup	For SGTR scenarios in which cooldown has failed, installing an automated RWST makeup system could provide an means of maintaining injection indefinitely. The makeup pump should be powered from a diesel backed bus. A boron source is required to ensure criticality does not occur. Including an alarm that identifies system actuation would provide an additional cue to address plant issues that have led to RWST depletion.	Braidwood Level 1 Importance Review	TMI estimated the cost of a similar SAMA to be $3,800,000 (Exelon 2008).	As the implementation cost is less than the MACR, this SAMA has been retained for Phase 2 analysis.

Table F.5-3
Braidwood Phase 1 SAMA List Summary

SAMA Number	SAMA Title	SAMA Description	Source	Cost Estimate	Phase 1 Baseline Disposition
15	Resolve Regulatory Issues and Complete Implementation of the Inter Unit AFW Cross-tie	The inter unit AFW cross-tie is in place at the site, but regulatory issues must be resolved before it can be considered "implemented". Once the process is complete, it will allow one unit to use the other unit's AFW system to provide SG makeup. The cross-tie valve requires local, manual action for operation.	Braidwood Level 1 Importance Review	Not Applicable	No significant expenditures are required to complete this enhancement, but the modification was not official at the time of the SAMA development and it is not credited in the PRA model of record. Retained for Phase 2 as a sensitivity analysis to demonstrate how crediting the cross-tie will impact the SAMA analysis.
16	Install High Flow Sensors On the Non-Essential Service Water System	Installing flow sensors in the WS lines with logic to trip the pumps on high flow conditions is a potential means of terminating WS flood events before critical systems are damaged.	Braidwood Level 1 Importance Review	Exelon estimates the cost of this SAMA to be $993,800.	As the implementation cost is less than the MACR, this SAMA has been retained for Phase 2 analysis.
17	Use AMASC for Alternate LOW SG Level AFW Initiation	For non-ATWS, the AMSAC logic could be used to provide a backup initiation signal for AFW. This would mitigate failures of the normal solid state protection system (SSPS) initiation system.	Braidwood LERF Importance Review	Exelon estimates the cost of this SAMA to be $981,730.	As the implementation cost is less than the MACR, this SAMA has been retained for Phase 2 analysis.

Table F.5-3
Braidwood Phase 1 SAMA List Summary

SAMA Number	SAMA Title	SAMA Description	Source	Cost Estimate	Phase 1 Baseline Disposition
18	Automate Refill of the Diesel Driven AFW Pump Fuel Oil Day Tank	The action to refill the diesel driven AFW pump fuel oil day tank is currently a manual action. Level sensors in the tank could be used to control a fill valve on the gravity feed line to automate the function, which would potentially improve system reliability.	Braidwood Level 1 Importance Review	Exelon estimates the cost of this SAMA to be $1,608,680.	As the implementation cost is less than the MACR, this SAMA has been retained for Phase 2 analysis.
19	Replace MOVs in the RHR Discharge Line with Valves that Can Isolate an ISLOCA Event	For cases in which the check valves fail in the RHR discharge line and an ISLOCA occurs, the event could be terminated if the containment isolation valves were capable of closing after the ISLOCA has occurred. Replacing the existing valves (MOVs _SI8809A, _SI8809B, and _SI8840) with an alternate design could provide this capability.	Braidwood Level 1 Importance Review	Wolf Creek Estimated $600,000 for two valves (WCNOC 2006), so $900,000 is assumed for the three valve change required for Braidwood.	As the implementation cost is less than the MACR, this SAMA has been retained for Phase 2 analysis.
20	Disallow On-Line RHR Maintenance	For cases in which one RHR train is out of service for maintenance, the plant is vulnerable to single failure events for certain initiating events that require heat removal (for example LOCAs). Preventing on-line RHR maintenance would prevent the associated core damage scenarios.	Braidwood Level 1 Importance Review	Exelon plant personnel estimate that moving the RHR maintenance to an outage would require 2-3 days of additional time each outage at a cost of about $1 million a day. For a two year cycle over 20 years, the total additional time would be 20-30 days for a total of $20 million to $30 million. $20 million is used here.	As the implementation cost is less than the MACR, this SAMA has been retained for Phase 2 analysis.

Table F.5-3
Braidwood Phase 1 SAMA List Summary

SAMA Number	SAMA Title	SAMA Description	Source	Cost Estimate	Phase 1 Baseline Disposition
21	Install an Emergency Isolation Valve in each of the RHR Suction Lines	For cases in which the two motor operated isolation valves in the RHR suction line fail and result in the overpressurization of the low pressure RHR piping, a LOCA outside containment can occur if the RHR piping breaks. In the event of a piping break, having an additional, normally open MOV located on the high pressure piping capable of closing against RCS pressure would provide a means of terminating the ISLOCA event.	Braidwood LERF Importance Review	For installing four new MOVs in the high pressure injection system (rather than replacing valves), TMI estimated a cost of $3,150,000 (Exelon 2008). For the two valves required by this SAMA, this cost is divided by two to yield about $1,600,000.	As the implementation cost is less than the MACR, this SAMA has been retained for Phase 2 analysis.
22	Install the Same High Flow Isolation Logic Used on Valve _CC685 on Valve _CC9438	In the event that an RCP Thermal Barrier Cooling heat exchangers breaks, the current in-containment relief valves are designed to relieve pressure at 2485 psig, which would be within the capacity of the piping up to the isolation boundary. However, if the Thermal Barrier Cooling Hx were to break and the isolation valve failed to close, the CC system could be over pressurized and inventory could be transferred outside containment through the 150 psid relief valves. A potential means of mitigating this event would be to install the same isolation logic used on valve _CC685 on valve_CC9438.	Braidwood LERF Importance Review	A similar valve logic change was estimated to be $250,000 in the Harris SAMA analysis (CPL 2006).	As the implementation cost is less than the MACR, this SAMA has been retained for Phase 2 analysis.

Table F.5-3
Braidwood Phase 1 SAMA List Summary

SAMA Number	SAMA Title	SAMA Description	Source	Cost Estimate	Phase 1 Baseline Disposition
23	Install a Passive Hydrogen Ignition System	For accident scenarios resulting in the generation of hydrogen in quantities sufficient to cause significant hydrogen detonations, containment failure is possible. A potential means of preventing these containment failure scenarios would be to install a passive hydrogen ignition system.	Braidwood LERF Importance Review	Calvert Cliffs estimated the cost of this enhancement to be $760,000 (BGE 1998).	As the implementation cost is less than the MACR, this SAMA has been retained for Phase 2 analysis.
24	Provide a Reactor Vessel Exterior Cooling System	This SAMA would provide the potential to cool a molten core before it causes vessel failure, if the lower head can be submerged in water. For Braidwood, use of existing emergency power is adequate to address the highest contributors.	Braidwood Late Release Importance Review	Calvert Cliffs estimated the cost of this enhancement to be $2,500,000 (BGE 1998), but it included its own power source. The cost is reduced by a factor of 2 to account for the use of existing power emergency power at Braidwood ($1,250,000).	As the implementation cost is less than the MACR, this SAMA has been retained for Phase 2 analysis.
25	Install a Filtered Containment Vent	This SAMA would provide a means of preventing long term containment overpressure failures by relieving pressure through a scrubbed release path. While post core damage venting is undesirable, a controlled scrubbed release is preferable to an un-scrubbed release through a containment break.	General Late Release Mitigation Method	Information for PWRs is limited, but the Limerick SAMDA analysis provided costs that ranged from $5.7 million to $11.3 million (PECO 1989). $5.7 million is used for this analysis.	As the implementation cost is less than the MACR, this SAMA has been retained for Phase 2 analysis.

Table F.5-3
Braidwood Phase 1 SAMA List Summary

SAMA Number	SAMA Title	SAMA Description	Source	Cost Estimate	Phase 1 Baseline Disposition
26	DMS Using a Dedicated Generator, Self-Cooled Charging Pump, and a Portable AFW Pump	This SAMA represents an alternate configuration of the DMS in which seal LOCAs are prevented using a seal injection system rather than by "no leak" seals. A dedicated 480V AC generator is proposed as a means of supporting long term SG makeup by maintaining the buses used for the battery chargers for SG level instrumentation and for powering a self-cooled primary side seal injection pump. A portable, engine driven SG makeup pump would provide an alternate means of SG makeup, with injection connections available on different divisions. Fire protection should provide both CST makeup and a suction source connection for the portable SG makeup pump. A means of providing borated makeup to the RWST is also required, which could potentially be performed using the fire protection system and an eductor. Finally, a connection point to an outside source would have to be provided for the containment spray system for long term spray capability in an SBO.	Industry SAMA Review	For this application, the cost estimate is derived from a reduced scope of equipment for simplicity. DC Cook estimated the cost of an RCP seal injection system with a dedicated diesel to be $2,000,000 (I&M 2003). The RCP seal injection DG is also assumed to support SG level instrumentation. To account for the cost of a portable SG makeup pump, the cost of a portable generator from Ginna (RG&E 2002) is used as a surrogate ($400,000). The total cost of the SAMA is $2,400,000.	As the implementation cost is less than the MACR, this SAMA has been retained for Phase 2 analysis.

Table F.5-3
Braidwood Phase 1 SAMA List Summary

SAMA Number	SAMA Title	SAMA Description	Source	Cost Estimate	Phase 1 Baseline Disposition
27	Protect RH, SI, and CVCS Cubicle Cooling Fan Cables in Fire Zone 11.3-0	While most of the equipment damage in the dominant fire scenario in zone 11.3-0 is related to the loss of MCC 132X1 (the ignition source), protecting the cables related to the RH, SI, and CVCS pump cubicle cooling fans may reduce the likelihood that room cooling will be failed for those pumps.	Braidwood Fire Results	Salem estimated the cost of installing cable wrap and fire barriers to maintain divisional separation to be $975,000 (PSEG 2009). While each fire barrier installation is unique, this is used as a rough estimate of the Braidwood cost.	As the implementation cost is less than the MACR, this SAMA has been retained for Phase 2 analysis.
28	Install Fire Barriers around MCC 132X4	Fires that start in this MCC are exacerbated by the propagation of the fire to nearby equipment. Installation of fire barriers to protect the equipment could mitigate the consequences of the fires.	Braidwood Fire Results	Salem estimated the cost of installing cable wrap and fire barriers to maintain divisional separation to be $975,000 (PSEG 2009). While each fire barrier installation is unique, this is used as a rough estimate of the Braidwood cost.	As the implementation cost is less than the MACR, this SAMA has been retained for Phase 2 analysis.

Table F.5-3
Braidwood Phase 1 SAMA List Summary

SAMA Number	SAMA Title	SAMA Description	Source	Cost Estimate	Phase 1 Baseline Disposition
29	Seal the Inverter 111 Panel and Install Fire Barriers to Protect Nearby Equipment	The fire scenario initiated by a fire in inverter 111 is exacerbated by propagation of the fire such that it damages nearby equipment. Limiting the damage of the fire to the inverter itself would reduce the risk of the fire event.	Braidwood Level 1 Internal Events and Fire Results	Salem estimated the cost of sealing 48 cabinets to be $3,230,000 (PSEG 2009). Sealing one cabinet would require about $67,000. In conjunction with sealing the cabinet, it is assumed that installation of fire barriers around nearby, critical equipment is half the $975,000 effort for the Salem SAMA related to installing cable wrap and installing fire barriers. The total cost for this SAMA, therefore, is $554,500.	As the implementation cost is less than the MACR, this SAMA has been retained for Phase 2 analysis.
30	Automate Swap to Recirculation Mode	Fully automating the swap to recirculation mode and removing the operator from the process can improve the reliability of the action.	Braidwood Fire Results	V.C. Summer estimated to cost of this enhancement to be $1,225,000 (SCE&GC 2002).	As the implementation cost is less than the MACR, this SAMA has been retained for Phase 2 analysis.

Table F.5-3
Braidwood Phase 1 SAMA List Summary

SAMA Number	SAMA Title	SAMA Description	Source	Cost Estimate	Phase 1 Baseline Disposition
31	Install Fire Barriers around MCCs 132X5 and 134X	Fires that start in these MCCs are exacerbated by the propagation of the fire to nearby equipment. Installation of fire barriers to protect the equipment could mitigate the consequences of the fires.	Braidwood Fire Results	Salem estimated the cost of installing cable wrap and fire barriers to maintain divisional separation to be $975,000 (PSEG 2009). While each fire barrier installation is unique, this is used as a rough estimate of the Braidwood cost.	As the implementation cost is less than the MACR, this SAMA has been retained for Phase 2 analysis.
32	Install Fire Barriers around MCC 131X2	Fires that start in this MCC are exacerbated by the propagation of the fire to nearby equipment. Installation of fire barriers to protect the equipment could mitigate the consequences of the fires.	Braidwood Fire Results	Salem estimated the cost of installing cable wrap and fire barriers to maintain divisional separation to be $975,000 (PSEG 2009). While each fire barrier installation is unique, this is used as a rough estimate of the Braidwood cost.	As the implementation cost is less than the MACR, this SAMA has been retained for Phase 2 analysis.
33	Unit 2 SAMA - Install Cable Wrap on the 141 to 241 4KV Cross-tie Cable in the Division 11 ESF Switchgear Room	Fires initiating in the 143 bus result in failure of bus 241. A potential means of preventing loss of bus 241 is to install cable wrap on the 141-241 cross-tie cable.	Braidwood Fire Results	Salem estimated the cost of installing cable wrap and fire barriers to maintain divisional separation to be $975,000 (PSEG 2009). While each fire barrier installation is unique, this is used as a rough estimate of the Braidwood cost.	As the implementation cost is less than the MACR, this SAMA has been retained for Phase 2 analysis.

Table F.5-3
Braidwood Phase 1 SAMA List Summary

SAMA Number	SAMA Title	SAMA Description	Source	Cost Estimate	Phase 1 Baseline Disposition
34	Unit 2 SAMA - Install Cable Wrap on the 141 to 241 4KV Cross-tie Cable in the Aux Building Elevation 426' of the General Area	Fires initiating in MCC 134X result in failure of bus 241. A potential means of preventing loss of bus 241 is to install cable wrap on the 141-241 cross-tie cable.	Braidwood Fire Results	Salem estimated the cost of installing cable wrap and fire barriers to maintain divisional separation to be $975,000 (PSEG 2009). While each fire barrier installation is unique, this is used as a rough estimate of the Braidwood cost.	As the implementation cost is less than the MACR, this SAMA has been retained for Phase 2 analysis.
35	Unit 2 SAMA - Install Cable Wrap to Protect 2AF005A, B, C, and D in the Division 21 Containment Electrical Penetrations Area	Fires initiating in MCC 231X2 and the pressurizer power supply transformer/panel result in failure of the 2AF005A-D valves. A potential means of preventing loss of division 1 AFW is to protect the cables related to the valves in this area.	Braidwood Fire Results	Salem estimated the cost of installing cable wrap and fire barriers to maintain divisional separation to be $975,000 (PSEG 2009). While each fire barrier installation is unique, this is used as a rough estimate of the Braidwood cost.	As the implementation cost is less than the MACR, this SAMA has been retained for Phase 2 analysis.

Table F.6-1
Braidwood Phase 2 SAMA List Summary

SAMA Number	SAMA Title	SAMA Description	Source	Phase 2 Baseline Disposition
1	Diesel Driven SX Pump	In order to mitigate CCF failure of the SX pumps, a diesel driven pump could be installed in a flood safe location with suction from the WS forebay that includes a suction strainer of an alternate design that is accessible for manual cleaning (in place of the pump discharge strainers). Auto start capability would be required to increase the benefit of the SAMA, but water level interlocks for critical rooms (e.g., SX pump rooms, Aux Building sump) may be required to prevent auto start in SX flooding evolutions.	Braidwood Level 1 Importance Review	This SAMA's net value is negative and is classified as not "cost beneficial".
2	Replace the Positive Displacement Pump with a Self-Cooled, Auto Start Pump	Loss of SX requires swap of the charging pump suction source to the RWST as well as alignment of an alternate lube oil cooling source to maintain RCP seal injection. Replacing the positive displacement pump with a self-cooled pump with the capability to auto start on loss of charging and SX flow would provide a means of seal cooling on loss of the normal pumps. Providing an automatic transfer switch to allow power from either division would enhance the SAMA's capability.	Braidwood Level 1 Importance Review	This SAMA's net value is negative and is classified as not "cost beneficial".
3	Auto Start of Standby SX Pump	Automating the start of the standby SX pump would help reduce the reliance of operators to maintain cooling to critical loads. Use of flooding interlocks could be used to prevent auto actuation in flooding scenarios.	Braidwood Level 1 Importance Review	This SAMA's net value is positive and is classified as potentially "cost beneficial".
4	Install "No Leak" RCP Seals	For loss of RCP seal cooling scenarios, a passive means of reducing the probability of an RCP seal LOCA is to replace the existing pump seals with "no leak" seals (e.g., Westinghouse "shield" seals) that are less likely to fail on loss of cooling.	Braidwood Level 1 Importance Review	This SAMA's net value is negative and is classified as not "cost beneficial".

Table F.6-1
Braidwood Phase 2 SAMA List Summary

SAMA Number	SAMA Title	SAMA Description	Source	Phase 2 Baseline Disposition
5	Modify the Startup Feedwater Pump to Start Using the AMSAC SG Low-Low-Low Level signal to Mitigate AFW Failure	For accident sequences in which main feedwater has tripped and AFW has failed to start, it is necessary to manually restart the FW system for continued SG makeup. By modifying the startup feedwater pump to auto start and align on low steam generator level, the need for operator intervention after AFW failure is essentially eliminated. Use of the AMSAC low-low-low SG level signal is an additional benefit that mitigates start signal failures.	Braidwood Level 1 Importance Review	This SAMA's net value is positive and is classified as potentially "cost beneficial".
6	Enhance Plant Procedures to Explicitly Confirm Adequate _SX007 Throttling	Due to variability in the temperature of the lake that serves as the water source for the Braidwood SX system, the _SX007 valve must be throttled to ensure the heat removal system is adequately balanced after RH initiation. Currently, the procedures do not explicitly require an independent check of the throttling action. Enhancing the procedures to explicitly direct such an independent check would improve the assessed reliability of the throttling action.	Braidwood Level 1 Importance Review	This SAMA's net value is positive and is classified as potentially "cost beneficial".
7	Establish Flow to the RH HX on RH Pump Start	To prevent overheating the RH pumps when they are operating on min-flow without CC cooling to the heat exchangers, procedure EP-0 (and potentially others) could be changed to direct the operators to align CC to the RH HX when the RH pumps start. This precludes the need for the operators to rely on a continuous action statement to protect the RH pumps if secondary side cooling is not established.	Braidwood Level 1 Importance Review	This SAMA's net value is positive and is classified as potentially "cost beneficial".

Table F.6-1
Braidwood Phase 2 SAMA List Summary

SAMA Number	SAMA Title	SAMA Description	Source	Phase 2 Baseline Disposition
8	Install Kill Switches for the Fire Protection Pumps in the MCR	Currently, it is not possible to terminate all flow from the fire protection system in the MCR. In the event of a flood caused by a fire protection system break, the availability of controls in the MCR that would allow the operators to shut down the fire protection pumps would increase the likelihood that the flood could be terminated before critical equipment is damaged.	Braidwood Level 1 Importance Review	This SAMA's net value is positive and is classified as potentially "cost beneficial".
9	Install Flow Restrictors in Fire Protection Pipes	Large breaks in the fire protection systems are significant contributors to plant risk. Installing flow restrictors in the auxiliary building piping would increase the time available to respond to these flooding events. Locating flow restrictors outside the auxiliary building upstream of valves 0FP209A, 0FP209B, and FP033 would provide adequate protection for auxiliary building floods.	Braidwood Level 1 Importance Review	This SAMA's net value is positive and is classified as potentially "cost beneficial".
10	Alter Ductwork Between the Aux Bldg Sump Drain Room and the SX Pump Room	Currently, the ductwork between the Auxiliary Building Sump Drain Room and the SX Pump Rooms provides a flowpath for flood water when the Auxiliary Building Sump Drain Room fills with water (at a depth of about 12 feet). Water then flows through the ductwork to the SX pump room and damages the SX pumps. Eliminating this pathway will increase the time available to mitigate the flooding event by precluding SX pump damage from the flooding event.	Braidwood Level 1 Importance Review	This SAMA's net value is positive and is classified as potentially "cost beneficial".

Table F.6-1
Braidwood Phase 2 SAMA List Summary

SAMA Number	SAMA Title	SAMA Description	Source	Phase 2 Baseline Disposition
11	Implement DMS	The diverse and flexible coping strategies (FLEX) guide identifies different means of addressing required plant functions in extreme accident conditions, but for the SAMA analysis a specific approach, called the Diverse Mitigation System (DMS), is proposed. A portable 480V AC generator is proposed as a means of supporting long term AFW operation by means of maintaining instrumentation and control power for the system by energizing the buses used for the battery chargers. A portable, engine driven SG makeup pump would provide an alternate means of SG makeup, with injection connections available on different divisions. Fire protection should provide both CST makeup and a suction source connection for the portable SG makeup pump. Use of high temperature RCP seals would limit primary system leakage and the positive displacement pump could be replaced by one that could be powered by the portable generator for long term RCS makeup. A means of providing borated makeup to the RWST is also required, which could potentially be performed using the fire protection system and an eductor. Finally, a connection point to an outside source would have to be provided for the containment spray system for long term spray capability in an SBO.	Braidwood Level 1 Importance Review	This SAMA's net value is positive and is classified as potentially "cost beneficial".

Table F.6-1
Braidwood Phase 2 SAMA List Summary

SAMA Number	SAMA Title	SAMA Description	Source	Phase 2 Baseline Disposition
13	Alternate AFW Cooling with Seal Protection	For loss of SX events with consequential LOOP, the AFW lube oil coolers are unavailable and the AFW pumps are assumed to fail. The AFW discharge flow could be routed back to the lube oil coolers to provide a self-cooling mechanism that would eliminate the SX dependence. The cooling water return path could potentially be returned to the AFW pump discharge path. For RCP seal protection, replacing the positive displacement pump with a self-cooled pump with the capability to auto start on loss of charging flow and/or high seal injection water temp would provide a success path.	Braidwood Level 1 Importance Review	This SAMA's net value is positive and is classified as potentially "cost beneficial".
14	Automated RWST Makeup	For SGTR scenarios in which cooldown has failed, installing an automated RWST makeup system could provide an means of maintaining injection indefinitely. The makeup pump should be powered from a diesel backed bus. A boron source is required to ensure criticality does not occur. Including an alarm that identifies system actuation would provide an additional cue to address plant issues that have led to RWST depletion.	Braidwood Level 1 Importance Review	This SAMA's net value is negative and is classified as not "cost beneficial".
15	Resolve Regulatory Issues and Complete Implementation of the Inter Unit AFW Cross-tie	The inter unit AFW cross-tie is in place at the site, but regulatory issues must be resolved before it can be considered "implemented". Once the process is complete, it will allow one unit to use the other unit's AFW system to provide SG makeup. The cross-tie valve requires local, manual action for operation.	Braidwood Level 1 Importance Review	This SAMA is in the final stages of implementation and no significant expenditures are required to complete this enhancement. Treated as potentially “cost beneficial” for the purposes of this analysis.

Table F.6-1
Braidwood Phase 2 SAMA List Summary

SAMA Number	SAMA Title	SAMA Description	Source	Phase 2 Baseline Disposition
16	Install High Flow Sensors On the Non-Essential Service Water System	Installing flow sensors in the WS lines with logic to trip the pumps on high flow conditions is a potential means of terminating WS flood events before critical systems are damaged.	Braidwood Level 1 Importance Review	This SAMA's net value is positive and is classified as potentially "cost beneficial".
17	Use AMASC for Alternate LOW SG Level AFW Initiation	For non-ATWS, the AMSAC logic could be used to provide a backup initiation signal for AFW. This would mitigate failures of the normal SSPS initiation system.	Braidwood LERF Importance Review	This SAMA's net value is negative and is classified as not "cost beneficial".
18	Automate Refill of the Diesel Driven AFW Pump Fuel Oil Day Tank	The action to refill the diesel driven AFW pump fuel oil day tank is currently a manual action. Level sensors in the tank could be used to control a fill valve on the gravity feed line to automate the function, which would potentially improve system reliability.	Braidwood Level 1 Importance Review	This SAMA's net value is negative and is classified as not "cost beneficial".
19	Replace MOVs in the RHR Discharge Line with Valves that Can Isolate an ISLOCA Event	For cases in which the check valves fail in the RHR discharge line and an ISLOCA occurs, the event could be terminated if the containment isolation valves were capable of closing after the ISLOCA has occurred. Replacing the existing valves (MOVs _SI8809A, _SI8809B, and _SI8840) with an alternate design could provide this capability.	Braidwood Level 1 Importance Review	This SAMA's net value is positive and is classified as potentially "cost beneficial".

Table F.6-1
Braidwood Phase 2 SAMA List Summary

SAMA Number	SAMA Title	SAMA Description	Source	Phase 2 Baseline Disposition
20	Disallow On-Line RHR Maintenance	For cases in which one RHR train is out of service for maintenance, the plant is vulnerable to single failure events for certain initiating events that require heat removal (for example LOCAs). Preventing on-line RHR maintenance would prevent the associated core damage scenarios.	Braidwood Level 1 Importance Review	This SAMA's net value is negative and is classified as not "cost beneficial".
21	Install an Emergency Isolation Valve in each of the RHR Suction Lines	For cases in which the two motor operated isolation valves in the RHR suction line fail and result in the overpressurization of the low pressure RHR piping, a LOCA outside containment can occur if the RHR piping breaks. In the event of a piping break, having an additional, normally open MOV located on the high pressure piping capable of closing against RCS pressure would provide a means of terminating the ISLOCA event.	Braidwood LERF Importance Review	This SAMA's net value is negative and is classified as not "cost beneficial".

Table F.6-1
Braidwood Phase 2 SAMA List Summary

SAMA Number	SAMA Title	SAMA Description	Source	Phase 2 Baseline Disposition
22	Install the Same High Flow Isolation Logic Used on Valve _CC685 on Valve _CC9438	In the event that an RCP Thermal Barrier Cooling heat exchangers breaks, the current in-containment relief valves are designed to relieve pressure at 2485 psig, which would be within the capacity of the piping up to the isolation boundary. However, if the Thermal Barrier Cooling Hx were to break and the isolation valve failed to close, the CC system could be over pressurized and inventory could be transferred outside containment through the 150 psid relief valves. A potential means of mitigating this event would be to install the same isolation logic used on valve _CC685 on valve_CC9438.	Braidwood LERF Importance Review	This SAMA's net value is negative and is classified as not "cost beneficial".
23	Install a Passive Hydrogen Ignition System	For accident scenarios resulting in the generation of hydrogen in quantities sufficient to cause significant hydrogen detonations, containment failure is possible. A potential means of preventing these containment failure scenarios would be to install a passive hydrogen ignition system.	Braidwood LERF Importance Review	This SAMA's net value is negative and is classified as not "cost beneficial".
24	Provide a Reactor Vessel Exterior Cooling System	This SAMA would provide the potential to cool a molten core before it causes vessel failure, if the lower head can be submerged in water. For Braidwood, use of existing emergency power is adequate to address the highest contributors.	Braidwood Late Release Importance Review	This SAMA's net value is negative and is classified as not "cost beneficial".

Table F.6-1
Braidwood Phase 2 SAMA List Summary

SAMA Number	SAMA Title	SAMA Description	Source	Phase 2 Baseline Disposition
25	Install a Filtered Containment Vent	This SAMA would provide a means of preventing long term containment overpressure failures by relieving pressure through a scrubbed release path. While post core damage venting is undesirable, a controlled scrubbed release is preferable to an un-scrubbed release through a containment break.	General Late Release Mitigation Method	This SAMA's net value is positive and is classified as potentially "cost beneficial".
26	DMS Using a Dedicated Generator, Self-Cooled Charging Pump, and a Portable AFW Pump	This SAMA represents an alternate configuration of the DMS in which seal LOCAs are prevented using a seal injection system rather than by "no leak" seals. A dedicated 480V AC generator is proposed as a means of supporting long term SG makeup by maintaining the buses used for the battery chargers for SG level instrumentation and for powering a self-cooled primary side seal injection pump. A portable, engine driven SG makeup pump would provide an alternate means of SG makeup, with injection connections available on different divisions. Fire protection should provide both CST makeup and a suction source connection for the portable SG makeup pump. A means of providing borated makeup to the RWST is also required, which could potentially be performed using the fire protection system and an eductor. Finally, a connection point to an outside source would have to be provided for the containment spray system for long term spray capability in an SBO.	Industry SAMA Review	This SAMA's net value is positive and is classified as potentially "cost beneficial".

Table F.6-1
Braidwood Phase 2 SAMA List Summary

SAMA Number	SAMA Title	SAMA Description	Source	Phase 2 Baseline Disposition
27	Protect RH, SI, and CVCS Cubicle Cooling Fan Cables in Fire Zone 11.3-0	While most of the equipment damage in the dominant fire scenario in zone 11.3-0 is related to the loss of MCC 132X1 (the ignition source), protecting the cables related to the RH, SI, and CVCS pump cubicle cooling fans may reduce the likelihood that room cooling will be failed for those pumps.	Braidwood Fire Results	This SAMA's net value is positive and is classified as potentially "cost beneficial".
28	Install Fire Barriers around MCC 132X4	Fires that start in this MCC are exacerbated by the propagation of the fire to nearby equipment. Installation of fire barriers to protect the equipment could mitigate the consequences of the fires.	Braidwood Fire Results	This SAMA's net value is positive and is classified as potentially "cost beneficial".

Table F.6-1
Braidwood Phase 2 SAMA List Summary

SAMA Number	SAMA Title	SAMA Description	Source	Phase 2 Baseline Disposition
29	Seal the Inverter 111 Panel and Install Fire Barriers to Protect Nearby Equipment	The fire scenario initiated by a fire in inverter 111 is exacerbated by propagation of the fire such that it damages nearby equipment. Limiting the damage of the fire to the inverter itself would reduce the risk of the fire event.	Braidwood Fire Results	This SAMA's net value is positive and is classified as potentially "cost beneficial".
30	Automate Swap to Recirculation Mode	Fully automating the swap to recirculation mode and removing the operator from the process can improve the reliability of the action.	Braidwood Fire Results	This SAMA's net value is negative and is classified as not "cost beneficial".
31	Install Fire Barriers around MCCs 132X5 and 134X	Fires that start in these MCCs are exacerbated by the propagation of the fire to nearby equipment. Installation of fire barriers to protect the equipment could mitigate the consequences of the fires.	Braidwood Fire Results	This SAMA's net value is negative and is classified as not "cost beneficial".

Table F.6-1
Braidwood Phase 2 SAMA List Summary

SAMA Number	SAMA Title	SAMA Description	Source	Phase 2 Baseline Disposition
32	Install Fire Barriers around MCC 131X2	Fires that start in this MCC are exacerbated by the propagation of the fire to nearby equipment. Installation of fire barriers to protect the equipment could mitigate the consequences of the fires.	Braidwood Fire Results	This SAMA's net value is negative and is classified as not "cost beneficial".
33	Unit 2 SAMA - Install Cable Wrap on the 141 to 241 4KV Cross-tie Cable in the Division 11 ESF Switchgear Room	Fires initiating in the 143 bus result in failure of bus 241. A potential means of preventing loss of bus 241 is to install cable wrap on the 141-241 cross-tie cable.	Braidwood Fire Results	This SAMA's net value is positive and is classified as potentially "cost beneficial".
34	Unit 2 SAMA - Install Cable Wrap on the 141 to 241 4KV Cross-tie Cable in the Aux Building Elevation 426' of the General Area	Fires initiating in MCC 134X result in failure of bus 241. A potential means of preventing loss of bus 241 is to install cable wrap on the 141-241 cross-tie cable.	Braidwood Fire Results	This SAMA's net value is negative and is classified as not "cost beneficial".

Table F.6-1
Braidwood Phase 2 SAMA List Summary

SAMA Number	SAMA Title	SAMA Description	Source	Phase 2 Baseline Disposition
35	Unit 2 SAMA - Install Cable Wrap to Protect 2AF005A, B, C, and D in the Division 21 Containment Electrical Penetrations Area	Fires initiating in MCC 231X2 and the pressurizer power supply transformer/panel result in failure of the 2AF005A-D valves. A potential means of preventing loss of division 1 AFW is to protect the cables related to the valves in this area.	Braidwood Fire Results	This SAMA's net value is negative and is classified as not "cost beneficial".

Table F.7-1
Generic Economic Sensitivity Case Values

Variable	Description	Base Case Value	Sensitivity Value
DPRATE[1]	Property depreciation rate (per yr)	0.20	0.20
DSRATE[2]	Investment rate of return (per yr)	0.07	0.07
EVACST[3]	Daily cost for a person who has been evacuated ($/person-day)	56.43	112.86
RELCST[3]	Daily cost for a person who is relocated ($/person-day)	56.43	112.86
POPCST[3]	Population relocation cost ($/person)	10,450	20,900
CDFRM0[3]	Cost of farm decontamination for two levels of decontamination ($/hectare) [5]	1,176 2,613	2,352 5,226
CDNFRM[3]	Cost of non-farm decontamination per resident person for various levels of decontamination ($/person) [5]	6,270 16,720	12,540 33,440
TIMDEC[1]	Decontamination time for each level[5]	2 & 4 months	2 & 12 months
DLBCST[3]	Average cost of decontamination labor ($/man-year)	73,150	146,300
TFWKF[1]	Time decontamination workers spend in farm land contaminated areas[5]	1/10 1/3	1/4 1/4
TWWNF[1]	Time decontamination workers spend in non-farm land contaminated areas[5]	1/3 1/3	1/4 1/4
VALWF0[4]	Value of farm wealth ($/hectare)	11,680	11,680
VALWNF[4]	Value of non-farm wealth ($/person)	297,748	297,748

(1) DPRATE uses NUREG/CR-4551 value (NRC 1990b).

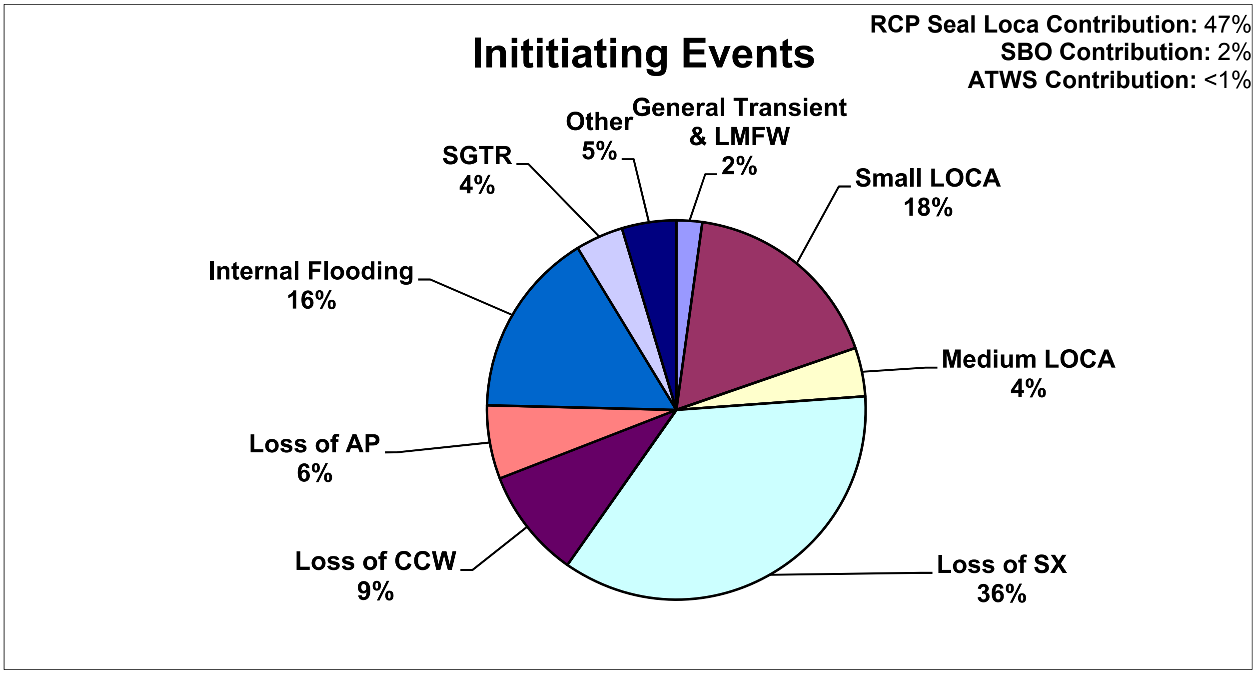
(2) DSRATE based on NUREG/BR-0058 (NRC 2004a).

(3) These parameters use the NUREG/CR-4551 values (NRC 1990b), updated to July 2012 using the consumer price index for base case. They are increased by a factor of 2 for sensitivity.

(4) VALWF0 and VALWNF are site specific values based on 2007 National Agriculture Census (USDA 2009) and Bureau of Economic Analysis 2007 data (BEA 2012), updated to the July 2012 using the consumer price index. They are not revised for the sensitivity case.

(5) Two decontamination levels are modeled, consistent with NUREG/CR-4551 (NRC 1990b). The first value is associated with a dose reduction factor of 3. The second value is associated with a dose reduction factor of 15. The dose reduction factors of 3 and 15 are not revised for the sensitivity case.

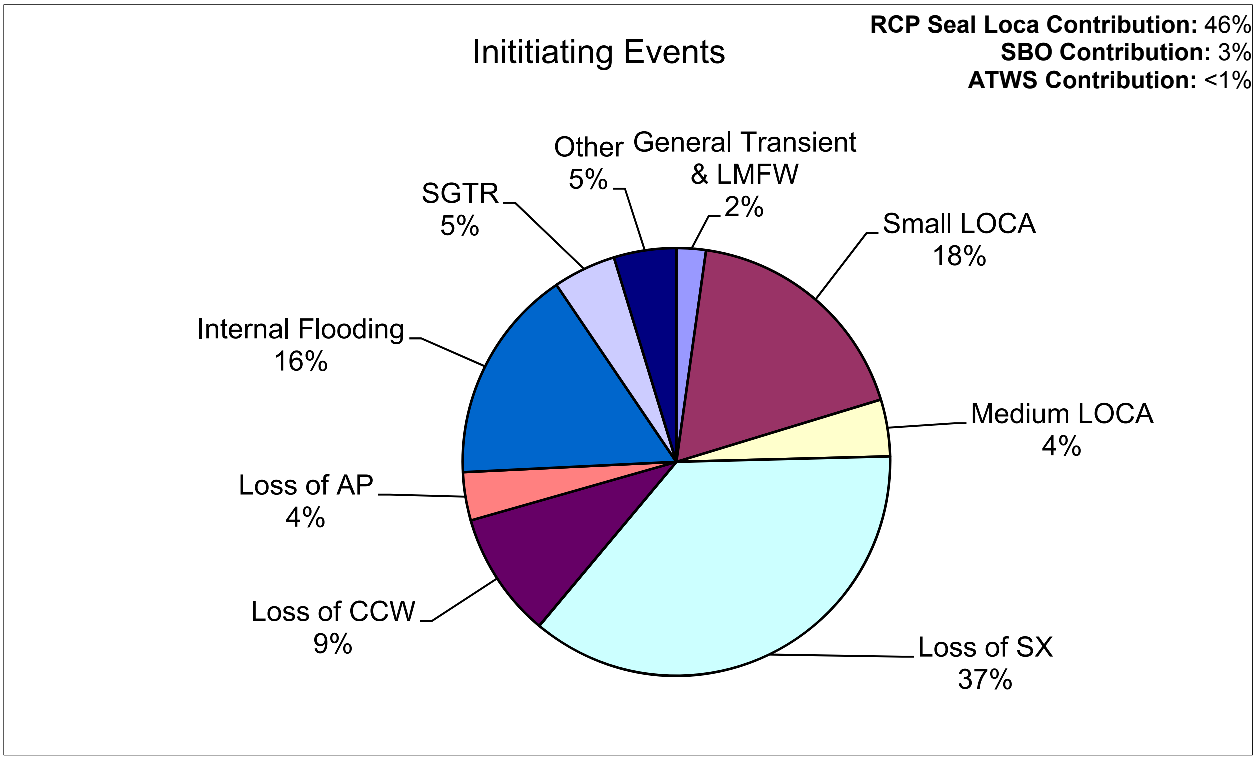
F.10 FIGURES



Initiating event[1]	CDF Contribution (based on percent contribution)
Loss of sx	**1.29E-05**
Small Loca	**6.42E-06**
internal flooding	**5.71E-06**
loss of ccw	**3.21E-06**
Loss of AP	**2.14E-06**
other	**1.78E-06**
medium loca	**1.43E-06**
sgtr	**1.43E-06**
Gen transient &lmfw	**7.14E-07**
Total	**3.57E-05**

1 THE CONTRIBUTIONS FROM THE CONSEQUENTIAL EVENTS ARE RCP SEAL LOCA: 1.68E-05, SBO: 7.14E-07, ATWS: <3.57E-07.

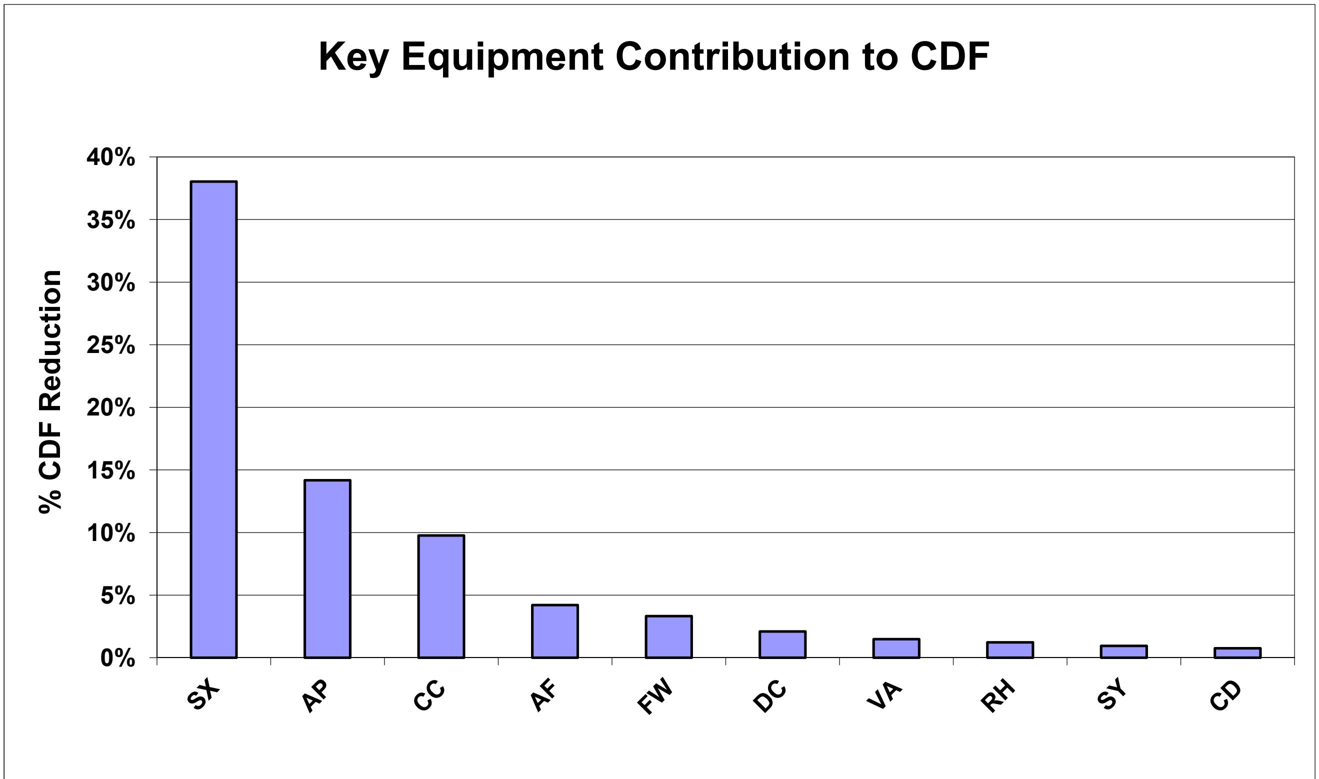
Figure F.2-1
Braidwood Unit 1 Contribution to CDF by Initiating Event



INITIATING EVENT	CDF CONTRIBUTION
Loss of sx	**1.30E-05**
Small Loca	**6.32E-06**
internal flooding	**5.62E-06**
loss of ccw	**3.16E-06**
other	**1.76E-06**
sgtr	**1.76E-06**
medium loca	**1.40E-06**
Loss of AP	**1.4E-06**
Gen transient &lmfw	**7.02E-07**
Total	**3.51E-05**

[2] The contributions from the consequential events are RCP seal LOCA: 1.61E-05, SBO: 1.05E-06, ATWS: <3.51E-07.

Figure F.2-2
Braidwood Unit 2 Contribution to CDF by Initiating Event



Key Equipment	
LEGEND	
System Acronym	System Name
SX	ESSENTIAL SERVICE WATER
CC	COMPONENT COOLING WATER
AP	AUXILIARY ELECTRIC POWER
AF	AUXILIARY FEEDWATER
FW	MAIN FEEDWATER
DC	DC POWER
SY	SWITCHYARD
RH	RESIDUAL HEAT REMOVAL
VA	AUXILIARY BUILDING HVAC
DG	DIESEL GENERATORS

Figure F.2-3
Unit 1 Fusell-Veselly by System based on CDF

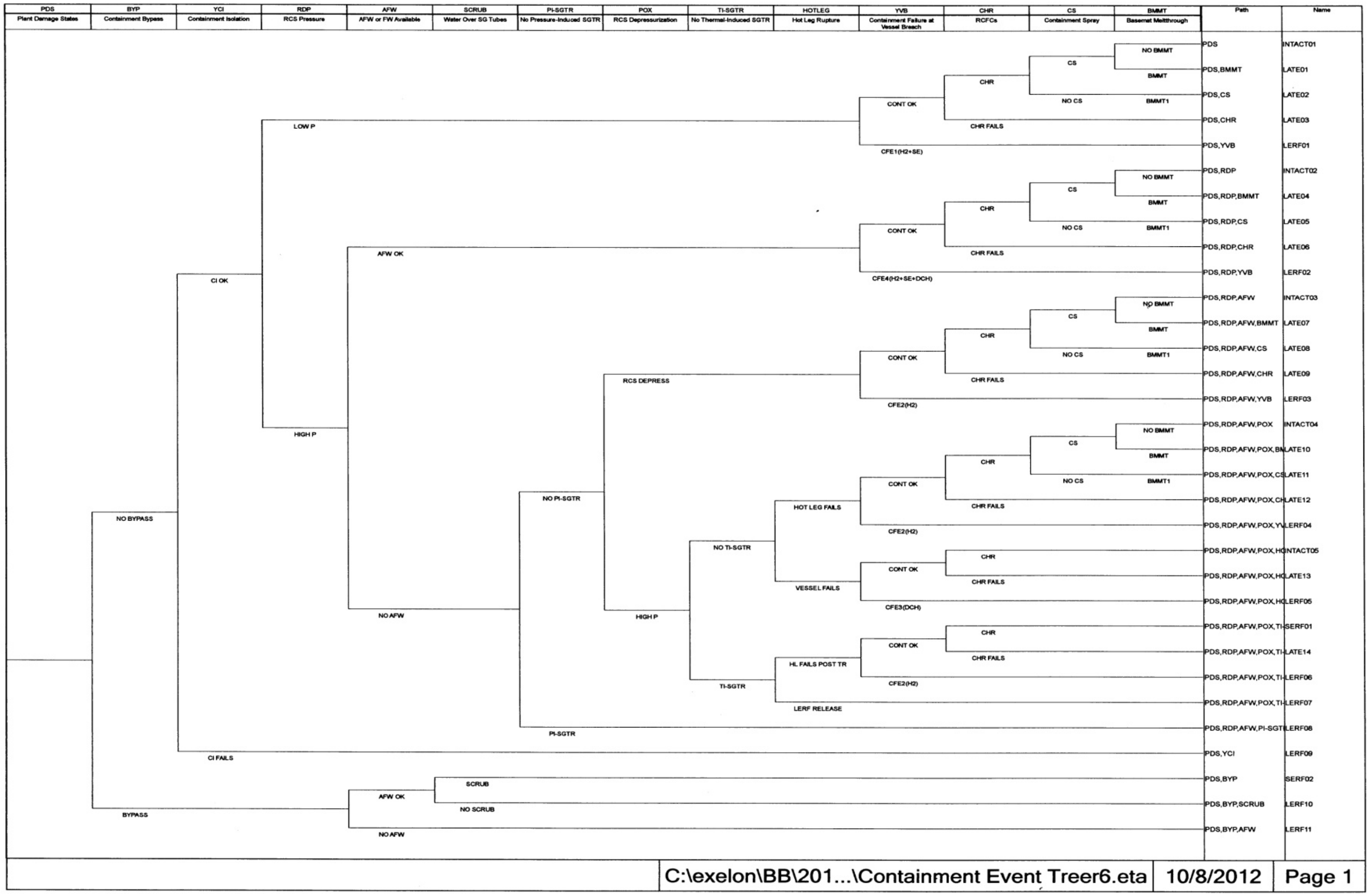


Figure F.2-4
Containment Event Tree

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