APR1400
ENVIRONMENTAL REPORT

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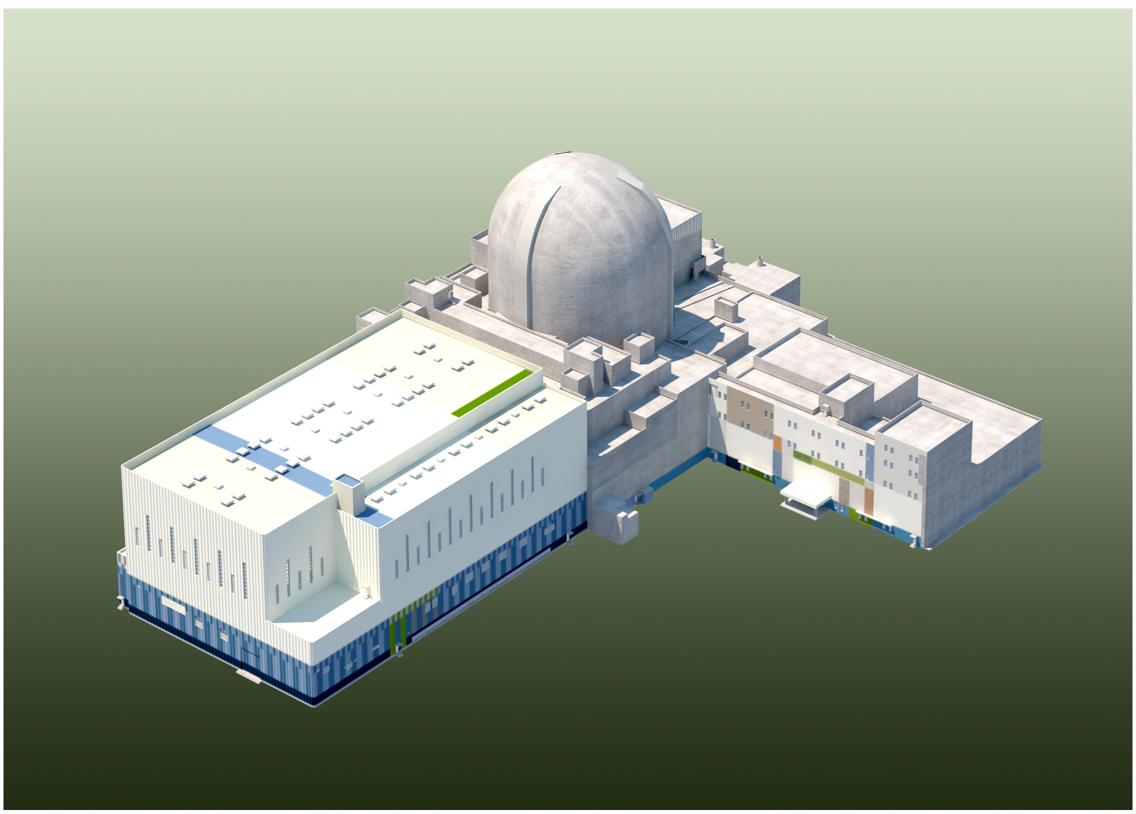

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ACRONYM AND ABBREVIATION LIST

The following is a list of acronyms and abbreviations used in this report. These abbreviations may be used in the chapter without an opening declaration of their meaning in the text of their definition (although one is usually provided).

AAC	Alternate Alternating Current
AC	Alternating Current
ADV	Atmospheric Dump Valve
AF	Auxiliary Feedwater
AFW	Auxiliary Feedwater
AFWST	Auxiliary Feedwater Storage Tank
AMSAC	ATWS Mitigation System Actuation Circuitry
AOC	Averted Off-site Property Damage Costs
AOE	Averted Occupational Exposures
AOSC	Averted On-site Costs
AOV	Air Operated Valve
APE	Averted Public Exposure
ATWS	Anticipated Transient Without Scram
BWR	Boiling Water Reactor
CDF	Core Damage Frequency
CE	Combustion Engineering
CFR	Code of Federal Regulations
COE	Cost of Enhancement
COL	Combined License
CS	Containment Spray
CST	Condensate Storage Tank
DC	Direct current
ECCS	Emergency Core Cooling System
ECSBS	Emergency Containment Spray Backup System
ECW	Essential Chilled Water
EDG	Emergency Diesel Generator

EOP	Emergency Operating Procedure
FSAR	Final Safety Analysis Report
GSI	Generic Safety Issue
HP/LP	High Pressure/Low Pressure
HVAC	Heating, Ventilation, and Air Conditioning
IRWST	In-Containment Refueling Water Storage Tank
ISLOCA	Interfacing System Loss of Coolant Accident
LOCA	Loss of Coolant Accident
LOOP	Loss of Offsite Power
LPSD	Low Power and Shutdown
LRF	Large Release Frequency
MCR	Main Control Room
MOV	Motor Operated Valve
MSIV	Main Steam Isolation Valve
NEI	Nuclear Energy Institute
NEPA	National Environmental Policy Act
NPV	Net Present Value
NRC	U.S. Nuclear Regulatory Commission
P&ID	Piping and Instrument Diagram
PAR	Passive Autocatalytic Recombiners
POSRV	Pilot Operated Safety Relief Valve
PRA	Probabilistic Risk Assessment
PV	Present Value
PW	Present Worth
RCP	Reactor Coolant Pump
RPV	Reactor Pressure Vessel
RSP	Remote Shutdown Panel
SAMA	Severe Accident Mitigation Alternative
SAMDA	Severe Accident Mitigation Design Alternative
SBO	Station Blackout
SG	Steam Generator

SGTR	Steam Generator Tube Rupture
SLC	Secondary Liquid Control
STC	Source Term Category

1.0 INTRODUCTION

This document provides an evaluation of severe accident mitigation design alternatives (SAMDA) for the APR1400 reactor. This evaluation is performed to address the potential costs and potential benefits of severe accident mitigation design alternatives for the APR1400 design. This document has been developed in accordance with applicable regulatory requirements as follows:

The National Environmental Policy Act (NEPA), Section 102.(C)(iii) requires, in part, that:

> ... all agencies of the Federal Government shall ... (C) include in every recommendation or report on proposals for legislation and other major Federal actions significantly affecting the quality of the human environment, a detailed statement by the responsible official on ... (iii) alternatives to the proposed action.

10 CFR 52.47(b)(2) requires the submittal of an environmental report as required by 10 CFR 51.55.

10 CFR 51.55 requires each applicant for a standard design certification to submit with its application a separate document entitled, "Applicant's Environmental Report—Standard Design Certification." The environmental report must address the costs and benefits of severe accident mitigation design alternatives, and the bases for not incorporating severe accident mitigation design alternatives in the design to be certified.

The report documents the calculation of the monetary value of unmitigated base risk then evaluates the maximum risk reduction that could be expected from implementing a risk reduction strategy. Consideration of SAMDAs includes identifying a broad range of potential alternatives then determining whether or not implementation of those alternatives is feasible or would be beneficial on a cost-risk reduction basis. This report also documents the identification, screening, and evaluation of SAMDAs for the APR1400 design certification.

2.0 METHODOLOGY

Consideration of alternatives to mitigate severe accidents involves the following steps.

a. Determine the base risk presented to the surrounding population and environment by plant operation.

b. Calculate the monetary value of the unmitigated base risk. The monetized value of base risk is the maximum averted risk that is possible.

c. Identify potential SAMDAs.

d. Screen all potential SAMDAs for applicability to the APR1400 and feasibility of implementation.

e. Evaluate potential SAMDAs not screened to determine the expected benefits of implementation for each.

f. Estimate the cost of implementing each SAMDA that is not screened.

g. Compare the estimated costs to the expected benefits to determine if implementation of any potential SAMDA would be cost-beneficial.

h. Evaluate how uncertainties could impact the cost-benefit analyses.

i. Perform sensitivity studies on the results.

3.0 BASE RISK

The first step to determine base risk is to develop and quantify an at-power, internal events Level 1 and Level 2 probabilistic risk assessment (PRA) model, which are discussed in the Section 19.1 of the Final Safety Analysis Report (FSAR). The results of the model provide overall risk measured by core damage frequency (CDF) and the characteristics of any expected radionuclide release following a severe accident.

The APR1400 PRA model also quantified internal fire, internal flooding, and low-power and shutdown (LPSD) events. Risk from other external events, for example, high winds, seismic events, etc., was determined to be negligible. Total CDF from the at-power internal events PRA is 1.3×10^{-6} per year and is calculated as the sum of the 21 source term categories (STCs) calculated from the Level 2 PRA model. Total CDF from internal flooding events is 4.0×10^{-7} per year. Fire-induced accident sequences had a calculated CDF of 1.9×10^{-6} per year. LPSD accident sequences had a calculated CDF of 2.7×10^{-6} per year. The total CDF from events other than full-power internal events is estimated to be 5.0×10^{-6} per year. Total CDF, therefore, is 6.3×10^{-6} per year and the ratio of total CDF to internal events CDF is 4.85. This factor can be used in later calculations to adjust benefits that are calculated using only the internal events STCs.

The second step in determining base risk is to identify the characteristics of any expected radionuclide release following a severe accident and then to quantify the expected frequency of release. The Level 2 PRA model characterizes releases into 21 STCs. Each of the STCs is distinguished by the magnitude of fission products released, the timing of the fission product release, and the pathway for the release. The STC definitions and contributions to the at-power internal events risk are presented in Table 1.

For each STC, representative releases are determined. The Level 2 analyzes representative sequences from each STC and develops timing and release characteristic information for representative fission product groups. This information is then used to approximate the radiological release plumes used in the Level 3 analysis.

Offsite consequences are calculated from the Level 3 PRA analysis. For each STC, the Level 3 PRA provides values for the conditional offsite dose and conditional offsite property damage that would result given that a fission product release with the plume characteristics used to represent the source term occurred. The total expected dose consequence is obtained by multiplying the conditional offsite dose by the expected frequency for each STC, then summing the expected

doses for all STCs. The conditional dose and expected dose for each STC along with the total expected dose are shown in Table 2. Similarly, the total expected property damage is obtained by multiplying the conditional property damage value by the expected frequency for each STC, then summing the expected property damage values for all STCs. The conditional property costs and expected property costs for each STC along with the total expected property costs are shown in Table 3.

4.0 UNMITIGATED RISK MONETARY VALUE

The unmitigated risk monetary value is calculated using the methodology given in Reference 1 for the performance of cost-benefit analyses. The value of unmitigated risk can be used to represent the maximum benefit that could be achieved if all risk was eliminated for at-power events. The methodology of Reference 3 determines the present worth net value of public risk according to the following formula:

$$NPV = (APE + AOC + AOE + AOSC) - COE \quad (1)$$

Where:

NPV = present value of current risk ($),

APE = present value of averted public exposure ($),

AOC = present value of averted offsite property damage costs ($),

AOE = present value of averted occupational exposure ($),

AOSC = present value of averted onsite costs ($)

COE = cost of any enhancement implemented to reduce risk ($).

The derivation of each of these costs is described in the subsections below. All equations used in the subsections below are taken from Reference 1.

The following specific values were used for various terms in the analyses:

Present Worth

The present worth was determined by:

$$PW = \frac{1 - e^{-rt}}{r} \quad (2)$$

Where:

r is the discount rate = 7% per year (assumed throughout these analyses)

t is the licensing period = 60 years (assuming a 40-year initial operating license and one 20-year license renewal)

PW is the present worth of a string of annual payments of one dollar = $14.07

Dollars per REM

The conversion factor used for assigning a monetary value to on-site and off-site exposures was \$2,000/person-rem averted. This is consistent with the NRC's regulatory analysis guidelines presented in and used throughout Reference 1.

4.1 Averted Public Exposure (APE)

Expected offsite doses from the internal events PRA accident sequences are presented in Table 2. Costs associated with these doses were calculated using the following equation:

$$APE = \left(F_S D_{PS} - F_A D_{PA}\right) R \frac{1 - e^{-rt_f}}{r} \quad (3)$$

Where:

- APE = present value of averted public exposure (\$),
- R = monetary equivalent of unit dose, (\$2000/person-rem),
- $F_S D_{PS}$ = baseline accident offsite dose frequency (person-rem per year from Table 2),
- $F_A D_{PA}$ = accident offsite dose frequency after mitigation (0 person-rem per year),
- r = real discount rate (7% per year),
- t_f = licensing period (60 years).

Using the values given above:

APE = (0.505 person-rem per year–0) × (\$2000/person-rem) × ((1 – $e^{-(0.07\times 60)}$)/(0.07 per year))

APE = \$14,209

4.2 Averted Offsite Property Damage Costs (AOC)

Annual expected offsite economic risk is shown in Table 3. The costs associated with AOC were calculated using the following equation:

$$AOC = \left(F_S P_{DS} - F_A P_{DA}\right) \frac{1 - e^{-rt_f}}{r} \quad (4)$$

Where:

AOC = present value of averted offsite property damage costs ($),

F_SP_{DS} = baseline accident frequency × property damage (cost per year from Table 3),

F_AP_{DA} = accident frequency × property damage after mitigation (0 events per year),

r = real discount rate (7% per year),

t_f = licensing period (60 years).

Using the values given above:

$$AOC = (\$1{,}391 \text{ per year} - 0) \times (1 - e^{-(0.07 \times 60)}) / (0.07 \text{ per year})$$

$$AOC = \$19{,}571$$

4.3 Averted Occupational Exposure (AOE)

There are two types of occupational exposure due to accidents: immediate and long-term. Immediate exposure occurs at the time of the accident and during the immediate management of the emergency. Long-term exposure is associated with the cleanup and refurbishment or decommissioning of the damaged facility. The value of avoiding both types of exposure must be considered when evaluating risk.

The occupational exposure associated with severe accidents was assumed to be 23,300 person-rem/accident. This value includes a short-term component of 3,300 person-rem/accident and a long-term component of 20,000 person-rem/accident. These estimates are consistent with the "best estimate" values presented in Section 5.7.3 of Reference 2. In calculating base risk, the accident-related onsite exposures were calculated using the best estimate exposure components applied over the on-site cleanup period. For onsite cleanup, the accident-related on-site exposures were calculated over a 10-year cleanup period. Costs associated with immediate dose, long-term dose and total dose are calculated below for internal events, internal flooding events, fires, and LPSD events.

4.4 Averted Immediate Occupational Exposure Costs

Per the guidance of Reference 1, costs associated with immediate occupational doses from an accident were calculated using the following equation:

$$W_{IO} = (F_S D_{IOS} - F_A D_{IOA}) R \frac{1 - e^{-rt_f}}{r} \quad (5)$$

Where:

- W_{IO} = present value of averted immediate occupational exposure ($),
- F_S = baseline accident frequency (events per year from Table 1),
- F_A = accident frequency after mitigation (0 events per year),
- D_{IOS} = baseline expected immediate onsite dose (3300 person-rem/event),
- D_{IOA} = expected occupational exposure after mitigation (3300 person-rem/event),
- R = monetary equivalent of unit dose, ($2000/person-rem),
- r = real discount rate (7% per year),
- t_f = licensing period (60 years).

Using the values given above:

W_{IO} = (1.3E-06 events per year) × (3300 person-rem/event) – 0) × ($2000/person-rem) × (1 – $e^{-(0.07 \times 60)}$) / (0.07 per year)

W_{IO} = $122

4.5 Averted Long-Term Occupational Exposure Costs

Per the guidance of Reference 2, costs associated with long-term occupational doses from an accident were calculated using the following equation:

$$W_{LTO} = (F_S D_{LTOS} - F_A D_{LTOA}) R \times \frac{1 - e^{-rt_f}}{r} \times \frac{1 - e^{-rm}}{rm} \quad (6)$$

Where:

- W_{LTO} = present value of averted long-term occupational exposure ($),
- F_S = baseline accident frequency (events per year from Table 1),
- F_A = accident frequency after mitigation (0 events per year),
- D_{LTOS} = baseline expected long-term onsite dose (20,000 person-rem/event),
- D_{LTOA} = expected occupational exposure after mitigation (20,000 person-rem/event),

R	=	monetary equivalent of unit dose, ($2000/person-rem),
r	=	real discount rate (7% per year),
m	=	years over which long-term doses accrue (10 years from Reference 2)
t_f	=	licensing period (60 years).

Using the values given above:

$$W_{LTO} = ((1.3E\text{-}06 \text{ events per year}) \times (20{,}000 \text{ person-rem/event}) - 0) \times (\$2000/\text{person-rem}) \times ((1 - e^{-(0.07 \times 60)}) / (0.07 \text{ per year}) \times ((1 - e^{-(0.07 \times 10)}) / ((0.07 \text{ per year}) \times (10 \text{ years}))$$

$$W_{LTO} = \$530$$

4.5.1 Total Averted Occupational Exposure Costs

As described in Section 4.3, the total cost associated with averted occupational exposure, AOE, is the sum of the costs associated with averted immediate exposure and the costs associated with the averted long-term exposure, or:

$$AOE = W_{IO} + W_{LTO} = \$122 + \$530 \quad (7)$$

$$AOE = \$652$$

4.6 Averted Onsite Costs (AOSC)

Reference 2 defines three types of costs associated with onsite property damage from an accident: cleanup and decontamination, long-term replacement power, and repair and refurbishment. The value of avoiding each of these types of costs must be considered when evaluating risk. Total averted onsite property damage costs are the sum of the three types of costs. Calculation of onsite property damage costs is detailed in the sections that follow.

4.6.1 Averted Cleanup and Decontamination Costs

The estimated cleanup cost for severe accidents was defined in Section 5.7.6.1 of Reference 2 to be $\$1.5\times10^9$/event (undiscounted). Using the value of $\$1.5\times10^9$/event and assuming, as in Reference 2, that the total sum is paid in equal installments over a ten year period, the present

value of those ten payments for cleanup and decontamination costs for the cleanup period can be calculated as follows:

$$PV_{CD} = \left(\frac{C_{CD}}{m}\right)\left(\frac{1-e^{-rm}}{r}\right) \quad (8)$$

Where:

PV_{CD}	=	present value of averted onsite cleanup costs exposure over cleanup period ($),
C_{CD}	=	total value of averted onsite cleanup costs ($),
r	=	real discount rate (7% per year),
m	=	years over which long-term doses accrue (10 years)

PV_{CD} = (($1.5E+09/event) / (10 years)) × ((1 – $e^{-(0.07 \times 10)}$) / 0.07)

PV_{CD} = $\$1.0787 \times 10^9$

The present value of the costs over the cleanup period must be considered over the period of license renewal. The net present value of averted cleanup costs over the license renewal period can be calculated using the following equation:

$$U_{CD} = (F_S - F_A)\, PV_{CD} \frac{1-e^{-rt_f}}{r} \quad (9)$$

Where:

U_{CD}	=	present value of averted onsite cleanup costs ($),
F_S	=	baseline accident frequency (events per year from Table 1),
F_A	=	accident frequency after mitigation (0 events per year),
PV_{CD}	=	present value of averted onsite cleanup costs exposure over cleanup period ($),
r	=	real discount rate (7% per year),
t_f	=	licensing period (60 years).

Using the values given above:

U_{CD} = (1.3E-06 events per year – 0) × ($1.0787E+09) × (1 – $e^{-(0.07 \times 60)}$) / (0.07 per year)

U_{CD} = $19,884

4.6.2 Averted Replacement Power Costs

Replacement power costs, U_{RP}, are an additional contributor to onsite costs and can be calculated in accordance with Section 5.7.6.2 of Reference 2. Since replacement power will be needed for that time period following a severe accident until the end of the expected generating plant life, long-term power replacement calculations have been used. APR1400 is expected to have a net electrical output of 1400 MWe.

Replacement power cost calculations performed in Reference 2 are based on the 910 MWe reference plant. In applying the methodology used in Reference 2 to the APR1400 design, the equation was scaled for the 1400 MWe output of APR1400 plant. For discount rates between 5% and 10%, Reference 2 recommends that the present value of replacement power be calculated as follows:

$$PV_{RP} = \left(\frac{(\$1.2E+8)\dfrac{(Rated\ power)}{(910MWe)}}{r} \right)\left(1-e^{-rt_f}\right)^2 \qquad (10)$$

Where:

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

r = real discount rate (7% per year),

t_f = licensing period (60 years),

Rated Power = 1400 MWe.

Using the values given above:

PV_{RP} = (1.2E+08 × (1400 MWe / 910 MWe)) / (0.07 per year) × $(1 - e^{-(0.07 \times 60)})^2$

PV_{RP} = $2.559E+09

The replacement power costs "PV_{RP}" ($\$2.559 \times 10^9$) was adjusted to 2012 dollars by applying a ratio of the average BLS Producer Price Index for Electric Power from years 1993 and 2012. The Producer Price Index for Electric Power for 2012 is 190.5, and the Producer Price Index for Electric Power for 1993 is 128.6 (Reference 3). The 2012 dollars scaling factor is calculated as 190.5/128.6, which equals 1.48.

The replacement power costs "PV_{RP}" was also adjusted to reflect the true need for replacement capacity availability based on current operations. A more realistic capacity factor of 95% is used in lieu of the suggested 60% - 65% range reported in Reference 2. This adjustment was applied as a simple multiplier derived by dividing 95% by 60% to get a value of 1.58.

PVRP = $2.559E+09 × (1.48) × (1.58)

$PV_{RP} = \$5.984 \times 10^9$

To obtain the expected costs of a single event over the license renewal period, the following equation is used:

$$U_{RP} = (F_S - F_A)\frac{PV_{RP}}{r}\left(1 - e^{-rt_f}\right)^2 \quad (11)$$

Where:

U_{RP} = present value of averted onsite cleanup costs ($),

F_S = baseline accident frequency (events per year from Table 1),

F_A = accident frequency after mitigation (0 events per year),

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

r = real discount rate (7% per year),

t_f = licensing period (60 years).

Using the values given above:

U_{RP} = (1.3E-06 events per year - 0) × (($5.984E+09) / (0.07 per year)) × $(1 - e^{-(0.07 \times 60)})^2$

U_{RP} = *$120,727*

4.6.3 Averted Repair and Refurbishment Costs

It is assumed that the plant would not be repaired or refurbished; therefore, these costs are zero.

4.6.4 Total Averted Onsite Costs (AOSC)

Total averted onsite cost is the sum of cleanup and decontamination costs, replacement power costs, and the repair and refurbishment costs. Total averted onsite costs are calculated as follows:

$$AOSC = U_{CD} + U_{RP} + 0 = \$19,884 + \$122,787 \quad (12)$$

$$AOSC = \$140,611$$

4.7 Cost of Enhancement (COE)

The cost of enhancement is used when measures are taken to reduce risk. By definition, such measures are taken at the beginning of any period considered, so no discounting is performed for the COE. For baseline risk, no measures have been taken to reduce risk, so:

$$COE = \$0$$

4.8 Total Unmitigated Baseline Risk

As described in Section 4.0, the total present worth net value of public risk is calculated according to the following formula:

$$NPV = (APE + AOC + AOE + AOSC) – COE \quad (1)$$

Using the values calculated in Sections 4.1 to 4.5, total baseline risk is calculated:

$$NPV = (\$14,209 + \$19,571 + \$652 + \$140,611) – \$0$$

$$NPV = \$140,611$$

This value can be viewed as the maximum risk benefit attainable if all core damage scenarios from internal events are eliminated over the 60-years licensing period.

Since the models for events other than internal events were not explicitly quantified, the total benefit is adjusted upward using the factor shown in Section 3.0 to account for the potential

benefit that could be achieved if the other events were explicitly considered in the quantification. Therefore, the maximum available benefit used will be:

NPV = (\$140,611) × 4.85

NPV = \$848,959

5.0 IDENTIFICATION OF SAMDAS

The list of SAMA items evaluated for the APR1400 design is given in Table 4. Generic industry SAMAs that are to be considered are the 153 items that are identified in Table 4 of NEI-05-01 (Reference 1).

6.0 SAMDA SCREENING

The initial list of potential SAMDAs was developed from a generic list of sources related to many plant designs. Some of the items on the list were identified relatively recently, while others were identified some time ago. Given the wide diversity in age and sources of the potential SAMDAs, an initial screening is performed to identify the subset of potential SAMDAs that warranted a detailed evaluation.

Potential SAMDAs to be examined in detail are identified by exception. That is, a screening process is used to remove potential SAMDAs from consideration. Any potential SAMDAs not screened will undergo more detailed evaluation.

As described in Reference 1, items can be screened for several reasons. First, items were screened that were not applicable to the APR1400. For example, some items are associated with specific equipment that is not present in the APR1400 design. Items screened as not applicable are indicated as “Not Applicable” in the “Qualitative Screening” column of Table 4. A total of the 64 potential SAMDAs were screened as not applicable.

Next, items were identified that were effectively implemented in the APR1400-DC design. Items screened as effectively implemented are indicated as “Already Implemented” or “Effectively Implemented” in the “Qualitative Screening” column of Table 4. A total of the 64 potential SAMDAs were identified as effectively implemented in the APR1400-DC design. The reason for screening as “Already Implemented” or “Effectively Implemented” is provided in Table 4.

Other SAMDA items were screened because they would not be feasible to implement. An item would not be feasible if the cost to implement the SAMDA clearly would exceed the maximum benefit possible. Reference 1 allows items to be screened if they would be of low benefit. An item is of low benefit if it is from a non-risk-significant system and a change in reliability would have negligible impact on the risk profile. Items screened as infeasible to implement are indicated with either “Excessive Imp. Cost” or “Low Benefit” in the “Qualitative Screening” column of Table 4. A total of 25 potential SAMDAs were screened as not feasible.

Overall, all generic industry items delineated in Reference 1 have been screened from further consideration.

7.0 SAMDA BENEFIT EVALUATION

Because all SAMDA items have been screened, no detailed benefit evaluation is needed.

8.0 SAMDA COST EVALUATION

Because all SAMDA items have been screened, no detailed benefit evaluation is needed.

9.0 SAMDA COST-BENEFIT EVALUATION

Because all SAMDA items have been screened, no detailed benefit evaluation is needed.

10.0 SENSITIVITY ANALYSIS (THREE-PERCENT DISCOUNT RATE)

The parameters that influence the cost-benefit analyses of the SAMDA evaluations were examined to determine if a change in value for one of the parameters would change the conclusions of the evaluation. Equations for each of the four types of averted costs (see Section 4.0 each contain a term for the real discount rate and evaluation period. Therefore, a change in either of those terms would have a direct impact on the averted costs calculated.

Reference 1 recommends using a 7% discount rate for cost-benefit analyses and suggests that a 3% discount rate should be used for sensitivity analyses on the maximum benefit and the unscreened SAMDAs to indicate the sensitivity of the results to the choice of discount rate. This sensitivity case is discussed below.

The methodology of Reference 1 determines the present worth net value of public risk according to the following formula:

$$NPV = (APE + AOC + AOE + AOSC) - COE \quad (1)$$

Where:

NPV = present value of current risk ($),

APE = present value of averted public exposure ($),

AOC = present value of averted offsite property damage costs ($),

AOE = present value of averted occupational exposure ($),

AOSC = present value of averted onsite costs ($)

COE = cost of any enhancement implemented to reduce risk ($).

The derivation of each of these costs is described in the subsections below. All equations used in the subsections below are taken from Reference 1.

The following specific values were used for various terms in the analyses:

Present Worth

The present worth was determined by:

$$PW = \frac{1 - e^{-rt}}{r} \quad (2)$$

Where:

r is the discount rate = 3% per year (assumed throughout these analyses)

t is the licensing period = 60 years (assuming a 40-year initial operating license and one 20-year license renewal)

PW is the present worth of a string of annual payments of one dollar = $27.82

<u>*Dollars per REM*</u>

The conversion factor used for assigning a monetary value to on-site and off-site exposures was $2,000/person-rem averted. This is consistent with the NRC's regulatory analysis guidelines presented in and used throughout Reference 2.

10.1 <u>Averted Public Exposure (APE)</u>

Expected offsite doses are presented in Table 2. Costs associated with these doses were calculated using the following equation:

$$APE = (F_S D_{PS} - F_A D_{PA}) R \frac{1 - e^{-rt_f}}{r} \quad (3)$$

Where:

APE = present value of averted public exposure ($),

R = monetary equivalent of unit dose, ($2000/person-rem),

$F_S D_{PS}$ = baseline accident offsite dose frequency (person-rem per year from Tables 2),

$F_A D_{PA}$ = accident offsite dose frequency after mitigation (0 person-rem per year),

r = real discount rate (3% per year),

t_f = licensing period (60 years).

Using the values given above:

APE = (0.505 person-rem per year–0)×($2000/person-rem)×((1 – e – (0.03×60))/(0.03 per year))

APE = $28,095

10.2 Averted Offsite Property Damage Costs (AOC)

Annual expected offsite economic risk is shown in Table3. Costs associated with AOC were calculated using the following equation:

$$AOC = \left(F_S P_{DS} - F_A P_{DA}\right)\frac{1 - e^{-rt_f}}{r} \qquad (4)$$

Where:

AOC = present value of averted offsite property damage casts ($),

$F_S P_{DS}$ = baseline offsite property damage costs (cost per year from Table3),

$F_A P_{DA}$ = property damage costs after mitigation (0 events per year),

r = real discount rate (3% per year),

t_f = licensing period (60 years).

Using the values given above:

AOC = ($1,391 per year – 0) × (1 – $e^{-(0.03 \times 60)}$) / (0.03 per year)

AOC = $38,697

10.3 Averted Occupational Exposure (AOE)

There are two types of occupational exposure due to accidents: immediate and long-term. Immediate exposure occurs at the time of the accident and during the immediate management of the emergency. Long-term exposure is associated with the cleanup and refurbishment or decommissioning of the damaged facility. The value of avoiding both types of exposure must be considered when evaluating risk.

The occupational exposure associated with severe accidents was assumed to be 23,300 person-rem/accident. This value includes a short-term component of 3,300 person-rem/accident and a long-term component of 20,000 person-rem/accident. These estimates are consistent with the "best estimate" values presented in Reference 2. In calculating base risk, the accident-related onsite exposures were calculated using the best estimate exposure components applied over the on-site cleanup period. For onsite cleanup, the accident-related on-site exposures were

calculated over a 10-year cleanup period. Costs associated with immediate dose, long-term dose and total dose are calculated below for internal events, internal flooding events, fires, and LPSD events.

10.3.1 Averted Immediate Occupational Exposure Costs

Per the guidance of Reference 1, costs associated with immediate occupational doses from an accident were calculated using the following equation:

$$W_{IO} = (F_S D_{IOS} - F_A D_{IOA}) R \frac{1 - e^{-rt_f}}{r} \quad (5)$$

Where:

W_{IO} = present value of averted immediate occupational exposure ($),
F_S = baseline accident frequency (events per year from Table 1),
F_A = accident frequency after mitigation (0 events per year),
D_{IOS} = baseline expected immediate onsite dose (3300 person-rem/event),
D_{IOA} = expected occupational exposure after mitigation (3300 person-rem/event),
R = monetary equivalent of unit dose, ($2000/person-rem),
r = real discount rate (3% per year),
t_f = licensing period (60 years).

Using the values given above:

W_{IO} = ((1.3E-06 events per year) × (3300 person-rem/event) – 0) × ($2000/person-rem) × (1 – $e^{-(0.03 \times 60)}$) / (0.03 per year)

W_{IO} = $241

10.3.2 Averted Long-Term Occupational Exposure Costs

Per the guidance of Reference 1, costs associated with long-term occupational doses from an accident were calculated using the following equation:

$$W_{LTO} = \left(F_S D_{LTOS} - F_A D_{LTOA}\right) R \times \frac{1-e^{-rt_f}}{r} \times \frac{1-e^{-rm}}{rm} \quad (6)$$

Where:

W_{LTO} = present value of averted long-term occupational exposure ($),
F_S = baseline accident frequency (events per year from Table 1),
F_A = accident frequency after mitigation (0 events per year),
D_{LTOS} = baseline expected long-term onsite dose (20,000 person-rem/event),
D_{LTOA} = expected occupational exposure after mitigation (20,000 person-rem/event),
R = monetary equivalent of unit dose, ($2000/person-rem),
r = real discount rate (3% per year),
m = years over which long-term doses accrue (10 years)
t_f = licensing period (60 years).

Using the values given above:

W_{LTO}= ((1.3E-06 events per year) × (20,000 person-rem/event) – 0) × ($2000/person-rem) × ((1 – $e^{-(0.03 \times 60)}$) / (0.03 per year) × ((1 – $e^{-(0.03 \times 10)}$) / ((0.03 per year) × (10 years))

W_{LTO}= $1,260

10.3.3 Total Averted Occupational Exposure Costs

As described in Section 4.3.3, the total cost associated with averted occupational exposure, AOE, is the sum of the costs associated with averted immediate exposure and the costs associated with the averted long-term exposure, or:

$$AOE = W_{IO} + W_{LTO} = \$241 + \$1,260 \quad (7)$$

AOE = $1,501

10.4 Averted Onsite Costs (AOSC)

Reference 1 defines three types of costs associated with onsite property damage from an accident: cleanup and decontamination, long-term replacement power, and repair and refurbishment. The

value of avoiding each of these types of costs must be considered when evaluating risk. Total averted onsite property damage costs are the sum of the three types of costs. Calculation of onsite property damage costs is detailed in the sections that follow.

10.4.1 Averted Cleanup and Decontamination Costs

The estimated cleanup cost for severe accidents was defined in Reference 2, to be $\$1.5\times10^9$/event (undiscounted). Using the value of $\$1.5\times10^9$/event and assuming, as in Reference 2, that the total sum is paid in equal installments over a ten year period, the present value of those ten payments for cleanup and decontamination costs for the cleanup period can be calculated as follows:

$$PV_{CD} = \left(\frac{C_{CD}}{m}\right)\left(\frac{1-e^{-rm}}{r}\right) \tag{8}$$

Where:

PV_{CD} = present value of averted onsite cleanup costs exposure over cleanup period ($),

C_{CD} = total value of averted onsite cleanup costs ($),

r = real discount rate (3% per year),

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

PV_{CD} = ((\$1.5E+09/event) / (10 years)) × ((1 – $e^{-(0.03 \times 10)}$) / 0.03)

PV_{CD} = \$1.2959E+09

The present value of the costs over the cleanup period must be considered over the period of operation with one license renewal. The net present value of averted cleanup costs over the license renewal period can be calculated using the following equation:

$$U_{CD} = (F_S - F_A)\,PV_{CD}\,\frac{1-e^{-rt_f}}{r} \tag{9}$$

Where:

U_{CD} = present value of averted onsite cleanup costs ($),

F_S = baseline accident frequency (events per year from Table 1),

F_A = accident frequency after mitigation (0 events per year),

PV_{CD} = present value of averted onsite cleanup costs exposure over cleanup period ($),

r = real discount rate (3% per year),

t_f = licensing period (60 years).

Using the values given above:

U_{CD} = (1.3E-06 events per year – 0) × ($1.2959E+09) × (1 – $e^{-(0.03 \times 60)}$) / (0.03 per year)

U_{CD} = $47,233

10.4.2 Averted Replacement Costs

Calculation of replacement power costs, however, requires a change in the equation in Section 4.4.2. Instead of using the equations shown in Section 4.4.2 to calculate U_{RP}, Reference 2 recommends using a linear interpolation between $\$1.9\times10^{10}$ for a discount rate of one percent and $\$1.2\times10^{10}$ for a discount rate of five percent. The replacement power cost must also be adjusted to 2012 dollars and again for the more realistic capacity factor of 95%. As detailed in Section 4.4.2, two multiplies are added to account for these adjustments:

2012 Dollars Scaling Factor Multiplier:	1.48
95% Capacity Factor Multiplier:	1.58

These multipliers are applied to equations documented in Sections 10.4.2.

Replacement power costs are calculated as detailed below.

U_{RP} = ($1.9E+10 - (($1.9E+10 - 1.2E+10) / (1% - 5%)) × (1% - 3%)) × (1400 MWe / 910 MWe) × (1.3E-06 events per year - 0) × (1.48) × (1.58)

U_{RP} = $81,167

10.4.3 Averted Repair and Refurbishment Costs

It is assumed that the plant would not be repaired or refurbished; therefore, these costs are zero.

10.4.4 Total Averted Onsite Costs (AOSC)

Total averted onsite cost is the sum of cleanup and decontamination costs, replacement power costs, and the repair and refurbishment costs. Total averted onsite costs are calculated as follows:

$$\text{AOSC} = U_{CD} + U_{RP} + 0 = \$47{,}233 + \$81{,}167 \quad (12)$$

$$\text{AOSC} = \$128{,}400$$

10.5 Cost of Enhancement (COE)

The cost of enhancement is used when measures are taken to reduce risk. By definition, such measures are taken at the beginning of any period considered, so no discounting is performed for the COE. For baseline risk, no measures have been taken to reduce risk, so:

$$\text{COE} = \$0$$

10.6 Total Unmitigated Baseline Risk

As described in Section 10.0, the total present worth net value of public risk is calculated according to the following formula:

$$\text{NPV} = (\text{APE} + \text{AOC} + \text{AOE} + \text{AOSC}) - \text{COE} \quad (1)$$

Using the values calculated in Sections 10.1 to 10.5, total baseline risk is calculated:

$$\text{NPV} = (\$28{,}095 + \$38{,}697 + \$1{,}501 + \$128{,}400) - \$0$$

$$\text{NPV} = \$196{,}693$$

This value can be viewed as the maximum risk benefit attainable if all core damage scenarios from internal events are eliminated over the 60-year license period.

Since the models for events other than internal events were not explicitly quantified, the total benefit is adjusted upward using the factor shown in Section 3.0 to account for the potential benefit that could be achieved if the other events were explicitly considered in the quantification. Therefore, the maximum available benefit used will be:

$$NPV = (\$196{,}693) \times 4.85$$
$$NPV = \$953{,}961$$

10.7 Screening of SAMDA Items Using the Three Percent Discount Rate

Using maximum benefit calculated for the three percent discount rate above, the SAMDA items in Table 4 were reviewed and screened again. No changes to the screening results were identified using the higher maximum benefit value.

11.0 CONCLUSIONS

The analyses described in the previous sections analyzed conceptual alternatives for mitigating severe accident impacts in the APR1400 design. Preliminary screening eliminated all SAMDA candidates from further consideration, based on inapplicability to the APR1400 design, design features that have already been incorporated into the APR1400 design, inapplicability to a design certification analysis, or extremely high cost of the alternatives considered.

12.0 REFERENCES

1. NEI-05-01, "Severe Accident Mitigation Alternatives (SAMA) Analysis – Guidance Document," Rev. A, November 2005.
2. NUREG/BR-0184, "Regulatory Analysis Technical Evaluation Handbook," U. S. Nuclear Regulatory Commission, 1997.
3. Bureau of Labor Statistics' Producer Price Index for the commodity of "Electric Power" (BLS 2011| Producer Price Index-Commodities: Series Id: WPU054| 2012/1993) (retrieved March 21, 2013)

Table 1 Release Category Summary for At-Power Internal Events

STC	Description	STC Frequency (per year)
1	Steam generator tube rupture (SGTR) bypass of containment without fission product scrubbing	5.3E-08
2	SGTR bypass of containment with fission product scrubbing	2.4E-08
3	ISLOCAs without fission product scrubbing	5.3E-11
4	ISLOCAs with fission product scrubbing	6.5E-11
5	Containment isolation failure with containment spray	2.5E-09
6	Containment isolation failure without containment spray	1.2E-09
7	Containment failure before core damage with small (leak) failure of containment	1.1E-08
8	Containment failure before core damage with large (rupture failure of containment	1.3E-08
9	Core melt arrested in the reactor vessel	3.7E-07
10	No containment failure after core melt	7.6E-07
11	Containment basemat failure	1.3E-08
12	Early containment failure with small (leak) failure of containment	0.0E+00
13	Early containment failure with large (rupture) failure of containment	1.8E-09
14	Late containment failure with a dry cavity, containment spray operation, and a small (leak) failure of containment	4.3E-11
15	Late containment failure with a wet cavity, containment spray operation, and a small (leak) failure of containment	0.0E+00
16	Late containment failure with a dry cavity, no containment spray, and a small (leak) failure of containment	7.3E-12
17	Late containment failure with a wet cavity, no containment spray, and a small (leak) failure of containment	2.7E-08
18	Late containment failure with a dry cavity, containment spray operation, and a large (rupture) failure of containment	4.2E-10
19	Late containment failure with a wet cavity, containment spray operation, and a large (rupture) failure of containment	4.0E-09
20	Late containment failure with a dry cavity, no containment spray, and a large (rupture) failure of containment	1.2E-11
21	Late containment failure with a wet cavity, no containment spray, and large (rupture) failure of containment	3.0E-08
	Total	1.3E-06

Table 2 Offsite Exposure by Release Category for At-Power Internal Events

STC	Description	Expected Person-REM/year Offsite
1	Steam generator tube rupture (SGTR) bypass of containment without fission product scrubbing	3.4E-01
2	SGTR bypass of containment with fission product scrubbing	7.3E-04
3	ISLOCAs without fission product scrubbing	5.0E-04
4	ISLOCAs with fission product scrubbing	5.2E-04
5	Containment isolation failure with containment spray	8.7E-04
6	Containment isolation failure without containment spray	2.2E-03
7	Containment failure before core damage with small (leak) failure of containment	5.1E-02
8	Containment failure before core damage with large (rupture failure of containment	7.5E-02
9	Core melt arrested in the reactor vessel	6.4E-04
10	No containment failure after core melt	3.2E-03
11	Containment basemat failure	2.6E-04
12	Early containment failure with small (leak) failure of containment	-
13	Early containment failure with large (rupture) failure of containment	6.0E-03
14	Late containment failure with a dry cavity, containment spray operation, and a small (leak) failure of containment	7.5E-06
15	Late containment failure with a wet cavity, containment spray operation, and a small (leak) failure of containment	-
16	Late containment failure with a dry cavity, no containment spray, and a small (leak) failure of containment	3.7E-06
17	Late containment failure with a wet cavity, no containment spray, and a small (leak) failure of containment	3.2E-04
18	Late containment failure with a dry cavity, containment spray operation, and a large (rupture) failure of containment	1.2E-04
19	Late containment failure with a wet cavity, containment spray operation, and a large (rupture) failure of containment	2.3E-03
20	Late containment failure with a dry cavity, no containment spray, and a large (rupture) failure of containment	9.5E-06
21	Late containment failure with a wet cavity, no containment spray, and large (rupture) failure of containment	2.3E-02
	Total	5.1E-01

Table 3 Offsite Property Damage Costs by Source Term Category

STC	Description	Conditional Property Costs ($)	Expected Property Costs ($)
1	Steam generator tube rupture (SGTR) bypass of containment without fission product scrubbing	1.86E+10	991
2	SGTR bypass of containment with fission product scrubbing	5.00E+07	1
3	ISLOCAs without fission product scrubbing	2.77E+10	1
4	ISLOCAs with fission product scrubbing	2.09E+10	1
5	Containment isolation failure with containment spray	3.91E+08	1
6	Containment isolation failure without containment spray	4.02E+09	5
7	Containment failure before core damage with small (leak) failure of containment	1.00E+10	114
8	Containment failure before core damage with large (rupture failure of	1.56E+10	203
9	Core melt arrested in the reactor vessel	3.17E+07	12
10	No containment failure after core melt	3.01E+07	23
11	Containment basemat failure	4.24E+07	1
12	Early containment failure with small (leak) failure of containment	-	-
13	Early containment failure with large (rupture) failure of containment	5.67E+09	10
14	Late containment failure with a dry cavity, containment spray operation, and a small (leak) failure of containment	5.86E+07	0
15	Late containment failure with a wet cavity, containment spray operation, and a small (leak) failure of containment	-	-
16	Late containment failure with a dry cavity, no containment spray, and a small (leak) failure of containment	3.43E+08	0
17	Late containment failure with a wet cavity, no containment spray, and a small (leak) failure of containment	3.34E+07	1
18	Late containment failure with a dry cavity, containment spray operation, and a large (rupture) failure of containment	1.05E+08	0
19	Late containment failure with a wet cavity, containment spray operation, and a large (rupture) failure of containment	3.60E+08	1
20	Late containment failure with a dry cavity, no containment spray, and a large (rupture) failure of containment	6.68E+08	0
21	Late containment failure with a wet cavity, no containment spray, and large (rupture) failure of containment	8.42E+08	25
		Total	1391

Table 4 Initial List of Candidate Improvements for the APR1400 SAMDA Analysis (1 of 31)

SAMA ID (NEI-05-01)	Potential Enhancement (SAMA Title)	Result of Potential Enhancement	Qualitative Screening
Improvements Related to AC and DC Power			
1	Provide additional DC battery capacity.	Extended DC power availability during an SBO.	Effectively implemented – battery life is 16 hours
2	Replace lead-acid batteries with fuel cells	Extended DC Power availability during an SBO	Effectively implemented – battery life is 16 hours
3	Add additional battery charger or portable diesel-driven battery charger to existing DC system	Improved availability of DC power system	Effectively implemented – each train of DC has an installed spare battery charger
4	Improve DC bus load shedding.	Extended DC power availability during an SBO.	N/A - Enhancement due to procedure revisions are not applicable to the design certification stage of plant development.
5	Provide DC bus cross-ties.	Improved availability of DC power system.	Effectively implemented – The APR1400 has four independent trains of DC power.
6	Provide additional DC power to the 120/240V vital AC system.	Increased availability of the 120 V vital AC bus.	Effectively implemented – battery life is 16 hours
7	Add an automatic feature to transfer the 120V vital AC bus from normal to standby power.	Increased availability of the 120 V vital AC bus.	Already implemented – the inverters automatically transfer to the standby power supply.
8	Increase training on response to loss of two 120V AC buses which causes inadvertent actuation signals.	Improved chances of successful response to loss of two 120V AC buses.	N/A - Enhancement due to training is not applicable to the design certification stage of plant development SAMDA.
9	Provide an additional diesel generator.	Increased availability of on-site emergency AC power.	Effectively implemented – the APR1400 design includes four independent EDGs plus one additional alternate AC power source.

Table 4 (2 of 31)

SAMA ID (NEI-05-01)	Potential Enhancement (SAMA Title)	Result of Potential Enhancement	Qualitative Screening
Improvements Related to AC and DC Power			
10	Revise procedure to allow bypass of diesel generator trips.	Extended diesel generator operation.	N/A - Enhancement due to procedure revisions are not applicable to the design certification stage of plant development.
11	Improve 4.16-kV bus cross-tie ability.	Increased availability of on-site AC power.	N/A - Enhancement due to procedure revisions are not applicable to the design certification stage of plant development.
12	Create AC power cross-tie capability with other unit (multi-unit site)	Increased availability of on-site AC power.	N/A – the APR1400 is a single-unit design and enhancement due to procedure revisions are not applicable to the design certification stage of plant development
13	Install an additional, buried off-site power source.	Reduced probability of loss of off-site power.	N/A – site-specific item for COL applicant.
14	Install a gas turbine generator.	Increased availability of on-site AC power.	Effectively implemented – the AAC generator is a gas-turbine generator.
15	Install tornado protection on gas turbine generator.	Increased availability of on-site AC power.	N/A – site-specific item for COL applicant. Tornado risk was determined to be negligible for the design certification.
16	Improve uninterruptible power supplies.	Increased availability of power supplies supporting front-line equipment.	N/A – at the design certification stage, generic data is used. There is no basis to say that the UPS are more or less reliable than generic data.

Table 4 (3 of 31)

SAMA ID (NEI-05-01)	Potential Enhancement (SAMA Title)	Result of Potential Enhancement	Qualitative Screening
Improvements Related to AC and DC Power			
17	Create a cross-tie for diesel fuel oil (multiunit site).	Increased diesel generator availability.	N/A – the APR1400 is a single-unit design and enhancement due to procedure revisions are not applicable to the design certification stage of plant development
18	Develop procedures for replenishing diesel fuel oil.	Increased diesel generator availability.	N/A - Enhancement due to procedure revisions are not applicable to the design certification stage of plant development.
19	Use fire water system as a backup source for diesel cooling.	Increased diesel generator availability.	Low benefit – loss of cooling is a negligible contributor to overall risk based on cutset importance.
20	Add a new backup source of diesel cooling.	Increased diesel generator availability.	Low benefit – loss of cooling is a negligible contributor to overall risk based on cutset importance.
21	Develop procedures to repair or replace failed 4 KV breakers.	Increased probability of recovery from failure of breakers that transfer 4.16 kV nonemergency buses from unit station service transformers.	N/A - Enhancement due to procedure revisions are not applicable to the design certification stage of plant development.
22	In training, emphasize steps in recovery of off-site power after an SBO.	Reduced human error probability during off-site power recovery.	N/A - Enhancement due to training is not applicable to the design certification stage of plant development SAMDA.

Table 4 (4 of 31)

SAMA ID (NEI-05-01)	Potential Enhancement (SAMA Title)	Result of Potential Enhancement	Qualitative Screening
Improvements Related to AC and DC Power			
23	Develop a severe weather conditions procedure.	Improved off-site power recovery following external weather-related events.	N/A - Enhancement due to procedure revisions are not applicable to the design certification stage of plant development.
24	Bury off-site power lines.	Improved off-site power reliability during severe weather.	N/A – site-specific item for COL applicant.
Improvements Related to Core Cooling Systems			
25	Install an independent active or passive high pressure injection system.	Improved prevention of core melt sequences.	Effectively implemented – the APR1400 design includes four trains of safety injection.
26	Provide an additional high pressure injection pump with independent diesel.	Reduced frequency of core melt from small LOCA and SBO sequences.	Effectively implemented – the APR1400 design includes four trains of safety injection. Each train is provided with a dedicated emergency diesel generator.
27	Revise procedure to allow operators to inhibit automatic vessel depressurization in non-ATWS scenarios.	Extended HPCI and RCIC operation.	N/A - Enhancement due to procedure revisions are not applicable to the design certification stage of plant development.
28	Add a diverse low pressure injection system.	Improved injection capability.	Effectively implemented – the APR1400 design includes four trains of safety injection and the shutdown cooling system can be aligned for low-pressure injection.

Table 4 (5 of 31)

SAMA ID (NEI-05-01)	Potential Enhancement (SAMA Title)	Result of Potential Enhancement	Qualitative Screening
Improvements Related to Core Cooling Systems			
29	Provide capability for alternate injection via diesel-driven fire pump.	Improved injection capability.	Effectively implemented – the APR1400 design includes four trains of safety injection and the shutdown cooling system can be aligned for low-pressure injection.
30	Improve ECCS suction strainers.	Enhanced reliability of ECCS suction.	Effectively implemented per the requirements of GSI-191.
31	Add the ability to manually align emergency core cooling system recirculation.	Enhanced reliability of ECCS suction.	N/A – the APR1400 uses an in-containment refueling water storage tank thus eliminating the need for switchover to recirculation.
32	Add the ability to automatically align emergency core cooling system to recirculation mode upon refueling water storage tank depletion.	Enhanced reliability of ECCS suction.	N/A – the APR1400 uses an in-containment refueling water storage tank thus eliminating the need for switchover to recirculation.
33	Provide hardware and procedure to refill the reactor water storage tank once it reaches a specified low level.	Extended reactor water storage tank capacity in the event of a steam generator tube rupture.	N/A - Enhancement due to procedure revisions are not applicable to the design certification stage of plant development. Furthermore, the large capacity of the IRWST along with the automatic throttling of AFW to prevent SG overfill minimizes the need for this change.

Table 4 (6 of 31)

SAMA ID (NEI-05-01)	Potential Enhancement (SAMA Title)	Result of Potential Enhancement	Qualitative Screening
Improvements Related to Core Cooling Systems			
34	Provide an in-containment reactor water storage tank.	Continuous source of water to the safety injection pumps during a LOCA event, since water released from a breach of the primary system collects in the in-containment reactor water storage tank, and thereby eliminates the need to realign the safety injection pumps for long-term post-LOCA recirculation.	Already Implemented In Design
35	Throttle low pressure injection pumps earlier in medium or large-break LOCAs to maintain reactor water storage tank inventory.	Extended reactor water storage tank capacity.	N/A - Enhancement due to procedure revisions are not applicable to the design certification stage of plant development. Furthermore, the IRWST eliminates the need for recirculation.
36	Emphasize timely recirculation alignment in operator training.	Reduced human error probability associated with recirculation failure.	N/A - Enhancement due to training is not applicable to the design certification stage of plant development SAMDA.
37	Upgrade the chemical and volume control system to mitigate small LOCAs.	For a plant like the Westinghouse AP600, where the chemical and volume control system cannot mitigate a small LOCA, an upgrade would decrease the frequency of core damage.	Effectively implemented – the APR1400 design includes four trains of safety injection and only one is needed to mitigate a small LOCA.

Table 4 (7 of 31)

SAMA ID (NEI-05-01)	Potential Enhancement (SAMA Title)	Result of Potential Enhancement	Qualitative Screening
Improvements Related to Core Cooling Systems			
38	Change the in-containment reactor water storage tank suction from four check valves to two check and two air-operated valves.	Reduced common mode failure of injection paths.	N/A – the suction lines are normally-open MOVs thus common causes failure is not
39	Replace two of the four electric safety injection pumps with diesel-powered pumps.	Reduced common cause failure of the safety injection system. This SAMA was originally intended for the Westinghouse-CE System 80+, which has four trains of safety injection. However, the intent of this SAMA is to provide diversity within the high- and low-pressure safety injection systems.	Excessive Imp. Cost – the additional costs of two additional diesels and the associated support equipment would greatly exceed the maximum available benefit.
40	Provide capability for remote, manual operation of secondary side pilot-operated relief valves in a station blackout.	Improved chance of successful operation during station blackout events in which high area temperatures may be encountered (no ventilation to main steam areas).	Effectively implemented - ADVs will have manual control from MCR and RSP when MSIVs are closed
41	Create a reactor coolant depressurization system.	Allows low pressure emergency core cooling system injection in the event of small LOCA and high-pressure safety injection failure.	Effectively implemented - Safety Depressurization and Vent System
42	Make procedure changes for reactor coolant system depressurization.	Allows low pressure emergency core cooling system injection in the event of small LOCA and high-pressure safety injection failure.	Effectively implemented – the APR1400 design includes the capability for the shutdown cooling system to be aligned for low-pressure injection.

Table 4 (8 of 31)

SAMA ID (NEI-05-01)	Potential Enhancement (SAMA Title)	Result of Potential Enhancement	Qualitative Screening
Improvements Related to Cooling Water			
43	Add redundant DC control power for SW pumps.	Increased availability of ESW.	Low benefit – loss of control power for ESW pumps is a negligible contributor to overall risk based on cutset importance.
44	Replace ECCS pump motors with aircooled motors.	Elimination of ECCS dependency on component cooling system.	Already Implemented / SI Pump Motors are air cooled by room coolers
45	Enhance procedural guidance for use of cross-tied component cooling or service water pumps.	Reduced frequency of loss of component cooling water and service water.	N/A - Enhancement due to procedure revisions are not applicable to the design certification stage of plant development.
46	Add a service water pump.	Increased availability of cooling water.	Effectively implemented – each division of service water has two pumps with only one pump required for success.
47	Enhance the screen wash system.	Reduced potential for loss of SW due to clogging of screens.	Low benefit – Clogging of SW screens contributes less than six percent to contributor to overall risk based on cutset importance. The failure probability assumes common cause of all screens and is based on generic data. Changes to the data are not applicable at the design stage. Elimination of the conservative assumption that all strainers fail due to common cause would lessen the already-small contribution of clogging screens.

Table 4 (9 of 31)

SAMA ID (NEI-05-01)	Potential Enhancement (SAMA Title)	Result of Potential Enhancement	Qualitative Screening
Improvements Related to Cooling Water			
48	Cap downstream piping of normally closed component cooling water drain and vent valves.	Reduced frequency of loss of component cooling water initiating events, some of which can be attributed to catastrophic failure of one of the many single isolation valves.	Already Implemented / See 1-461 series drawings
49	Enhance loss of component cooling water (or loss of service water) procedures to facilitate stopping the reactor coolant pumps.	Reduced potential for reactor coolant pump seal damage due to pump bearing failure.	N/A - Enhancement due to procedure revisions are not applicable to the design certification stage of plant development.
50	Enhance loss of component cooling water procedure to underscore the desirability of cooling down the reactor coolant system prior to seal LOCA.	Reduced probability of reactor coolant pump seal failure.	N/A - Enhancement due to procedure revisions are not applicable to the design certification stage of plant development.
51	Additional training on loss of component cooling water.	Improved success of operator actions after a loss of component cooling water.	N/A - Enhancement due to training is not applicable to the design certification stage of plant development SAMDA.
52	Provide hardware connections to allow another essential raw cooling water system to cool charging pump seals.	Reduced effect of loss of component cooling water by providing a means to maintain the charging pump seal injection following a loss of normal cooling water.	Effectively implemented - two charging pumps are air cooled. The additional aux charging pump is a positive displacement type and requires no external cooling.
53	On loss of essential raw cooling water, proceduralize shedding component cooling water loads to extend the component cooling water heat-up time.	Increased time before loss of component cooling water (and reactor coolant pump seal failure) during loss of essential raw cooling water sequences.	N/A - Enhancement due to procedure revisions are not applicable to the design certification stage of plant development.

Table 4 (10 of 31)

SAMA ID (NEI-05-01)	Potential Enhancement (SAMA Title)	Result of Potential Enhancement	Qualitative Screening
Improvements Related to Cooling Water			
54	Increase charging pump lube oil capacity.	Increased time before charging pump failure due to lube oil overheating in loss of cooling water sequences.	Effectively implemented - two charging pumps are air cooled. The additional aux charging pump is a positive displacement type and requires no external cooling.
55	Install an independent reactor coolant pump seal injection system, with dedicated diesel.	Reduced frequency of core damage from loss of component cooling water, service water, or station blackout.	Effectively implemented – the RCP seals are expected to have a low failure probability and low leakage. Specifics of RCP seal design are to be verified by the COL applicant.
56	Install an independent reactor coolant pump seal injection system, without dedicated diesel.	Reduced frequency of core damage from loss of component cooling water or service water, but not a station blackout.	Effectively implemented – the RCP seals are expected to have a low failure probability and low leakage. Specifics of RCP seal design are to be verified by the COL applicant.
57	Use existing hydro test pump for reactor coolant pump seal injection.	Reduced frequency of core damage from loss of component cooling water or service water, but not a station blackout.	Effectively implemented – the RCP seals are expected to have a low failure probability and low leakage. Specifics of RCP seal design are to be verified by the COL applicant.
58	Install improved reactor coolant pump seals.	Reduced likelihood of reactor coolant pump seal LOCA.	Effectively implemented – the RCP seals are expected to have a low failure probability and low leakage. Specifics of RCP seal design are to be verified by the COL applicant.
59	Install an additional component cooling water pump.	Reduced likelihood of loss of component cooling water leading to a reactor coolant pump seal LOCA.	Effectively implemented – each division of component cooling water has two pumps with only one pump required for success.

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SAMA ID (NEI-05-01)	Potential Enhancement (SAMA Title)	Result of Potential Enhancement	Qualitative Screening
Improvements Related to Cooling Water			
60	Prevent makeup pump flow diversion through the relief valves.	Reduced frequency of loss of reactor coolant pump seal cooling if spurious high pressure injection relief valve opening creates a flow diversion large enough to prevent reactor coolant pump seal injection.	Effectively implemented – the RCP seals are expected to have a low failure probability and low leakage. The impact of this item on RCP seal LOCA would be minimal. Specifics of RCP seal design are to be verified by the COL applicant.
61	Change procedures to isolate reactor coolant pump seal return flow on loss of component cooling water, and provide (or enhance) guidance on loss of injection during seal LOCA.	Reduced frequency of core damage due to loss of seal cooling.	N/A - Enhancement due to procedure revisions are not applicable to the design certification stage of plant development.
62	Implement procedures to stagger high pressure safety injection pump use after a loss of service water.	Extended high pressure injection prior to overheating following a loss of service water.	N/A - Enhancement due to procedure revisions are not applicable to the design certification stage of plant development.
63	Use fire prevention system pumps as a backup seal injection and high pressure makeup source.	Reduced frequency of reactor coolant pump seal LOCA.	Effectively implemented – the RCP seals are expected to have a low failure probability and low leakage. The impact of this item on RCP seal LOCA would be minimal. Specifics of RCP seal design are to be verified by the COL applicant.
64	Implement procedure and hardware modifications to allow manual alignment of the fire water system to the component cooling water system, or install a component cooling water header cross-tie.	Improved ability to cool residual heat removal heat exchangers.	N/A - Enhancement due to procedure revisions are not applicable to the design certification stage of plant development.

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SAMA ID (NEI-05-01)	Potential Enhancement (SAMA Title)	Result of Potential Enhancement	Qualitative Screening
Improvements Related to Feedwater and Condensate			
65	Install a digital feed water upgrade.	Reduced chance of loss of main feed water following a plant trip.	Effectively implemented – the APR1400 uses digital controls.
66	Create ability for emergency connection of existing or new water sources to feedwater and condensate systems.	Increased availability of feedwater.	Effectively implemented – Each division of AFW has a dedicated storage tank. Makeup to the AFWST is available from the CST, demineralized water, and raw water.
67	Install an independent diesel for the condensate storage tank makeup pumps.	Extended inventory in CST during an SBO.	Effectively implemented – Each division of AFW has a dedicated storage tank. Makeup to the AFWST is available from the CST, demineralized water, and raw water.
68	Add a motor-driven feedwater pump.	Increased availability of feedwater.	Effectively implemented - APR1400 has 2 Turbine-driven AF pumps and 2 Motor-driven AF pumps.

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SAMA ID (NEI-05-01)	Potential Enhancement (SAMA Title)	Result of Potential Enhancement	Qualitative Screening
Improvements Related to Feedwater and Condensate			
69	Install manual isolation valves around auxiliary feedwater turbine-driven steam admission valves.	Reduced dual turbine-driven pump maintenance unavailability.	Already Implemented / See 1-526 series P&IDs, manual valves installed up and downstream of Steam Inlet Stop Valve (HP/LP)
70	Install accumulators for turbine-driven auxiliary feedwater pump flow control valves.	Eliminates the need for local manual action to align nitrogen bottles for control air following a loss of off-site power.	N/A - Steam Control Valves are Electro-Hydraulic operated

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SAMA ID (NEI-05-01)	Potential Enhancement (SAMA Title)	Result of Potential Enhancement	Qualitative Screening
Improvements Related to Feedwater and Condensate			
71	Install a new condensate storage tank (auxiliary feedwater storage tank).	Increased availability of the auxiliary feedwater system.	Effectively implemented – each division has a dedicated auxiliary feed water storage tank.

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SAMA ID (NEI-05-01)	Potential Enhancement (SAMA Title)	Result of Potential Enhancement	Qualitative Screening
Improvements Related to Feedwater and Condensate			
72	Modify the turbine-driven auxiliary feedwater pump to be self-cooled.	Improved success probability during a station blackout.	Already Implemented – turbine-driven AF pumps are designed to operate without room cooling
73	Proceduralize local manual operation of auxiliary feedwater system when control power is lost.	Extended auxiliary feedwater availability during a station blackout. Also provides a success path should auxiliary feedwater control power be lost in non-station blackout sequences.	N/A - Enhancement due to procedure revisions are not applicable to the design certification stage of plant development.
74	Provide hookup for portable generators to power the turbine-driven auxiliary feedwater pump after station batteries are depleted.	Extended auxiliary feedwater availability.	Effectively implemented – station batteries have a 16-hour capacity.
75	Use fire water system as a backup for steam generator inventory.	Increased availability of steam generator water supply.	Effectively implemented – Each division of AFW has a dedicated storage tank. Makeup to the AFWST is available from the CST, demineralized water, and raw water.
76	Change failure position of condenser makeup valve if the condenser makeup valve fails open on loss of air or power.	Allows greater inventory for the auxiliary feedwater pumps by preventing condensate storage tank flow diversion to the condenser.	Already Implemented / Condensate Storage Tank Makeup to Condenser AOVs Fail Closed (1-531 (1/5) P&ID) and the AFW system supply is independent of the CST.
77	Provide a passive, secondary-side heat rejection loop consisting of a condenser and heat sink.	Reduced potential for core damage due to loss-of-feedwater events.	Effectively implemented – the APR1400 design includes four redundant trains of AFW plus the startup feedwater pump. This arrangement minimizes the need for an additional secondary heat removal system.

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SAMA ID (NEI-05-01)	Potential Enhancement (SAMA Title)	Result of Potential Enhancement	Qualitative Screening
Improvements Related to Feedwater and Condensate			
78	Modify the startup feedwater pump so that it can be used as a backup to the emergency feedwater system, including during a station blackout scenario.	Increased reliability of decay heat removal.	Effectively implemented – the startup feedwater pump can be used as a backup to AFW if offsite power is available. Failure on SBO is dominated by offsite power recovery, not heat removal so little benefit would be gained by aligning the pump during SBO
79	Replace existing pilot-operated relief valves with larger ones, such that only one is required for successful feed and bleed.	Increased probability of successful feed and bleed.	Effectively implemented – success criteria evaluations have shown that two POSRVs are adequate for feed and bleed cooling.
Improvements Related to Heating, Ventilation, and Air Conditioning			
80	Provide a redundant train or means of ventilation.	Increased availability of components dependent on room cooling.	Effectively implemented – two divisions of essential chilled water are provided and auxiliary building cooling can be provided by emergency HVAC in the event that ECW is lost.
81	Add a diesel building high temperature alarm or redundant louver and thermostat.	Improved diagnosis of a loss of diesel building HVAC.	Already implemented – temperature alarm provided, refer to P&IDs for EDG room HVAC.
82	Stage backup fans in switchgear rooms.	Increased availability of ventilation in the event of a loss of switchgear ventilation.	N/A – HVAC for switchgear rooms not required per the design.
83	Add a switchgear room high temperature alarm.	Improved diagnosis of a loss of switchgear HVAC.	N/A – HVAC for switchgear rooms not required per the design.

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SAMA ID (NEI-05-01)	Potential Enhancement (SAMA Title)	Result of Potential Enhancement	Qualitative Screening
Improvements Related to Heating, Ventilation, and Air Conditioning			
84	Create ability to switch emergency feedwater room fan power supply to station batteries in a station blackout.	Continued fan operation in a station blackout.	Already Implemented / turbine-driven AF pumps are designed to operate without room cooling
Improvements Related to Instrument Air and Nitrogen Supply			
85	Provide cross-unit connection of uninterruptible compressed air supply.	Increased ability to vent containment using the hardened vent.	N/A - Enhancement due to procedure revisions are not applicable to the design certification stage of plant development.
86	Modify procedure to provide ability to align diesel power to more air compressors.	Increased availability of instrument air after a LOOP.	N/A - Enhancement due to procedure revisions are not applicable to the design certification stage of plant development.
87	Replace service and instrument air compressors with more reliable compressors which have self-contained air cooling by shaft driven fans.	Elimination of instrument air system dependence on service water cooling.	N/A – instrument air compressors use turbine building cooling water, not essential service water.
88	Install nitrogen bottles as backup gas supply for safety relief valves.	Extended SRV operation time.	N/A – the APR1400 uses POSRVs that operate using system pressure.
89	Improve SRV and MSIV pneumatic components.	Improved availability of SRVs and MSIVs.	N/A for SRVs as they are for BWRs only. N/A for MSIVs as they are electro-hydraulic operated.

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SAMA ID (NEI-05-01)	Potential Enhancement (SAMA Title)	Result of Potential Enhancement	Qualitative Screening
Improvements Related to Containment Phenomena			
90	Create a reactor cavity flooding system.	Enhanced debris cool ability, reduced core concrete interaction, and increased fission product scrubbing.	Already Implemented / Cavity Flooding System
91	Install a passive containment spray system.	Improved containment spray capability.	Effectively implemented – ESCBS provides a backup to the CS system.
92	Use the fire water system as a backup source for the containment spray system.	Improved containment spray capability.	Effectively implemented – ESCBS provides a backup to the CS system.
93	Install an unfiltered, hardened containment vent.	Increased decay heat removal capability for non-ATWS events, without scrubbing released fission products.	Excessive Imp. Cost – Based on current industry efforts related to post-Fukushima modifications, installation of this modification would greatly exceed the maximum available benefit
94	Install a filtered containment vent to remove decay heat Option 1: Gravel Bed Filter Option 2: Multiple Venturi Scrubber	Increased decay heat removal capability for non-ATWS events, with scrubbing of released fission products.	Excessive Imp. Cost – Based on current industry efforts related to post-Fukushima modifications, installation of this modification would greatly exceed the maximum available benefit
95	Enhance fire protection system and standby gas treatment system hardware and procedures.	Improved fission product scrubbing in severe accidents.	N/A –related to BWRs only.

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SAMA ID (NEI-05-01)	Potential Enhancement (SAMA Title)	Result of Potential Enhancement	Qualitative Screening
Improvements Related to Containment Phenomena			
96	Provide post-accident containment inerting capability.	Reduced likelihood of hydrogen and carbon monoxide gas combustion.	Low benefit – Because the APR1400 includes redundant passive autocatalytic hydrogen recombiners, any additional benefit would be small and the installation costs would exceed any potential benefit.
97	Create a large concrete crucible with heat removal potential to contain molten core debris.	Increased cooling and containment of molten core debris. Molten core debris escaping from the vessel is contained within the crucible and a water cooling mechanism cools the molten core in the crucible, preventing melt-through of the base mat.	Excessive Imp. Cost – This item affects only offsite release. Based on the potential benefits of eliminating all offsite consequences, the cost of this item would greatly exceed the potential benefit.
98	Create a core melt source reduction system.	Increased cooling and containment of molten core debris. Refractory material would be placed underneath the reactor vessel such that a molten core falling on the material would melt and combine with the material. Subsequent spreading and heat removal from the vitrified compound would be facilitated, and concrete attack would not occur.	Excessive Imp. Cost – This item affects only offsite release. Based on the potential benefits of eliminating all offsite consequences, the cost of this item would greatly exceed the potential benefit.
99	Strengthen primary/secondary containment (e.g., add ribbing to containment shell).	Reduced probability of containment over-pressurization.	Excessive Imp. Cost – This item affects only offsite release. Based on the potential benefits of eliminating all offsite consequences, the cost of this item would greatly exceed the potential benefit.

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SAMA ID (NEI-05-01)	Potential Enhancement (SAMA Title)	Result of Potential Enhancement	Qualitative Screening
Improvements Related to Containment Phenomena			
100	Increase depth of the concrete base mat or use an alternate concrete material to ensure melt-through does not occur.	Reduced probability of base mat melt-through.	Excessive Imp. Cost – This item affects only offsite release. Based on the potential benefits of eliminating all offsite consequences, the cost of this item would greatly exceed the potential benefit.
101	Provide a reactor vessel exterior cooling system.	Increased potential to cool a molten core before it causes vessel failure, by submerging the lower head in water.	Already implemented.
102	Construct a building to be connected to primary/secondary containment and maintained at a vacuum.	Reduced probability of containment over-pressurization.	Excessive Imp. Cost – This item affects only offsite release. Based on the potential benefits of eliminating all offsite consequences, the cost of this item would greatly exceed the potential benefit.
103	Institute simulator training for severe accident scenarios.	Improved arrest of core melt progress and prevention of containment failure.	N/A - Enhancement due to training is not applicable to the design certification stage of plant development SAMDA.
104	Improve leak detection procedures.	Increased piping surveillance to identify leaks prior to complete failure. Improved leak detection would reduce LOCA frequency.	N/A - Enhancement due to procedure revisions are not applicable to the design certification stage of plant development.
105	Delay containment spray actuation after a large LOCA.	Extended reactor water storage tank availability.	N/A - Enhancement due to procedure revisions are not applicable to the design certification stage of plant development.

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SAMA ID (NEI-05-01)	Potential Enhancement (SAMA Title)	Result of Potential Enhancement	Qualitative Screening
Improvements Related to Containment Phenomena			
106	Install automatic containment spray pump header throttle valves.	Extended time over which water remains in the reactor water storage tank, when full containment spray flow is not needed.	N/A – the APR1400 uses an in-containment refueling water storage tank thus eliminating the need for switchover to recirculation.
107	Install a redundant containment spray system.	Increased containment heat removal ability.	Effectively implemented – ESCBS provides a backup to the CS system.
108	Install an independent power supply to the hydrogen control system using either new batteries, a non-safety grade portable generator, existing station batteries, or existing AC/DC independent power supplies, such as the security system diesel.	Reduced hydrogen detonation potential.	Effectively implemented – see item 109 below.
109	Install a passive hydrogen control system.	Reduced hydrogen detonation potential.	Already Implemented / Hydorgen Control System includes 2 redundant passive autocatalytic recombiners (PARs) system.
110	Erect a barrier that would provide enhanced protection of the containment walls (shell) from ejected core debris following a core melt scenario at high pressure.	Reduced probability of containment failure.	Already implemented in cavity design.

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SAMA ID (NEI-05-01)	Potential Enhancement (SAMA Title)	Result of Potential Enhancement	Qualitative Screening
Improvements Related to Containment Bypass			
111	Install additional pressure or leak monitoring instruments for detection of ISLOCAs.	Reduced ISLOCA frequency.	Already implemented – pressure alarms provided on injection lines. See 441 series of P&IDs.
112	Add redundant and diverse limit switches to each containment isolation valve.	Reduced frequency of containment isolation failure and ISLOCAs.	Effectively implemented – multiple valves, beyond typical current-generation design, are provided on ISLOCA pathways.
113	Increase leak testing of valves in ISLOCA paths.	Reduced ISLOCA frequency.	N/A - Enhancement due to procedure revisions are not applicable to the design certification stage of plant development.
114	Install self-actuating containment isolation valves.	Reduced frequency of isolation failure.	Already Implemented / Cntmt Isolation System provides automatic and leaktight closure of those valves required to close for cntmt integrity
115	Locate residual heat removal (RHR) inside containment	Reduced frequency of ISLOCA outside containment.	Small benefit – ISLOCA contribution is not significant to APR1400 risk
116	Ensure ISLOCA releases are scrubbed. One method is to plug drains in potential break areas so that break point will be covered with water.	Scrubbed ISLOCA releases.	Excessive Imp. Cost – ISLOCAs are small contributors to overall risk and offsite costs are a minor contribution to overall benefit. Plugging drains in the area of ISLOCA break locations would require significant changes to auxiliary building flood barriers and floor drain pumps and sumps. The cost of this item would greatly exceed the potential benefit.

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SAMA ID (NEI-05-01)	Potential Enhancement (SAMA Title)	Result of Potential Enhancement	Qualitative Screening
Improvements Related to Containment Bypass			
117	Revise EOPs to improve ISLOCA identification.	Increased likelihood that LOCAs outside containment are identified as such. A plant had a scenario in which an RHR ISLOCA could direct initial leakage back to the pressurizer relief tank, giving indication that the LOCA was inside containment.	N/A - Enhancement due to procedure revisions are not applicable to the design certification stage of plant development.
118	Improve operator training on ISLOCA coping.	Decreased ISLOCA consequences.	N/A - Enhancement due to training is not applicable to the design certification stage of plant development SAMDA.
119	Institute a maintenance practice to perform a 100% inspection of steam generator tubes during each refueling outage.	Reduced frequency of steam generator tube ruptures.	N/A - Enhancement due to training is not applicable to the design certification stage of plant development SAMDA.
120	Replace steam generators with a new design.	Reduced frequency of steam generator tube ruptures.	Already implemented – the APR1400 uses the latest design of SGs.
121	Increase the pressure capacity of the secondary side so that a steam generator tube rupture would not cause the relief valves to lift.	Eliminates release pathway to the environment following a steam generator tube rupture.	Excessive Imp. Cost – SGTR events contribute less than four percent to overall risk. Based on the potential benefits of eliminating all offsite consequences and all core damage from SGTR sequences, the cost of this item would greatly exceed the potential benefit.

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SAMA ID (NEI-05-01)	Potential Enhancement (SAMA Title)	Result of Potential Enhancement	Qualitative Screening
Improvements Related to Containment Bypass			
122	Install a spray system to depressurize the primary system during a steam generator tube rupture	Enhanced depressurization capabilities during steam generator tube rupture.	Effectively implemented – primary depressurization can be effected by POSRVs, normal spray, auxiliary spray, or the reactor coolant gas vent system.
123	Proceduralize use of pressurizer vent valves during steam generator tube rupture sequences.	Backup method to using pressurizer sprays to reduce primary system pressure following a steam generator tube rupture.	N/A - Enhancement due to procedure revisions are not applicable to the design certification stage of plant development.
124	Provide improved instrumentation to detect steam generator tube ruptures, such as Nitrogen-16 monitors).	Improved mitigation of steam generator tube ruptures.	Already Implemented / N-16 monitors are provided.
125	Route the discharge from the main steam safety valves through a structure where a water spray would condense the steam and remove most of the fission products.	Reduced consequences of a steam generator tube rupture.	Excessive Imp. Cost – SGTR events contribute less than four percent to overall risk. Based on the potential benefits of eliminating all offsite consequences and all core damage from SGTR sequences, the cost of this item would greatly exceed the potential benefit.
126	Install a highly reliable (closed loop) steam generator shell-side heat removal system that relies on natural circulation and stored water sources	Reduced consequences of a steam generator tube rupture.	Excessive Imp. Cost – SGTR events contribute less than four percent to overall risk. Based on the potential benefits of eliminating all offsite consequences and all core damage from SGTR sequences, the cost of this item would greatly exceed the potential benefit.

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SAMA ID (NEI-05-01)	Potential Enhancement (SAMA Title)	Result of Potential Enhancement	Qualitative Screening
Improvements Related to Containment Bypass			
127	Revise emergency operating procedures to direct isolation of a faulted steam generator.	Reduced consequences of a steam generator tube rupture.	N/A - Enhancement due to procedure revisions are not applicable to the design certification stage of plant development.
128	Direct steam generator flooding after a steam generator tube rupture, prior to core damage.	Improved scrubbing of steam generator tube rupture releases.	N/A - Enhancement due to procedure revisions are not applicable to the design certification stage of plant development.
129	Vent main steam safety valves in containment.	Reduced consequences of a steam generator tube rupture.	Excessive Imp. Cost – SGTR events contribute less than four percent to overall risk. Based on the potential benefits of eliminating all offsite consequences and all core damage from SGTR sequences, the cost of this item would greatly exceed the potential benefit.

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SAMA ID (NEI-05-01)	Potential Enhancement (SAMA Title)	Result of Potential Enhancement	Qualitative Screening
Improvements Related to ATWS			
130	Add an independent boron injection system.	Improved availability of boron injection during ATWS.	Excessive Imp. Cost – ATWS events contribute less than five four percent to overall risk. Based on the potential benefits of eliminating all offsite consequences and all core damage from ATWS sequences, the cost of this item would greatly exceed the potential benefit.
131	Add a system of relief valves to prevent equipment damage from pressure spikes during an ATWS.	Improved equipment availability after an ATWS.	Excessive Imp. Cost – ATWS events contribute less than five four percent to overall risk. Based on the potential benefits of eliminating all offsite consequences and all core damage from ATWS sequences, the cost of this item would greatly exceed the potential benefit.
132	Provide an additional control system for rod insertion (e.g., AMSAC).	Improved redundancy and reduced ATWS frequency.	Already implemented – diverse protection system is provided.
133	Install an ATWS sized filtered containment vent to remove decay heat.	Increased ability to remove reactor heat from ATWS events.	Excessive Imp. Cost – ATWS events contribute less than five four percent to overall risk. Based on the potential benefits of eliminating all offsite consequences and all core damage from ATWS sequences, the cost of this item would greatly exceed the potential benefit.

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SAMA ID (NEI-05-01)	Potential Enhancement (SAMA Title)	Result of Potential Enhancement	Qualitative Screening
Improvements Related to ATWS			
134	Revise procedure to bypass MSIV isolation in turbine trip ATWS scenarios.	Affords operators more time to perform actions. Discharge of a substantial fraction of steam to the main condenser (i.e., as opposed to into the primary containment) affords the operator more time to perform actions (e.g., SLC injection, lower water level, depressurize RPV) than if the main condenser was unavailable, resulting in lower human error probabilities.	N/A - Enhancement due to procedure revisions are not applicable to the design certification stage of plant development.
135	Revise procedure to allow override of low pressure core injection during an ATWS event.	Allows immediate control of low pressure core injection. On failure of high pressure core injection and condensate, some plants direct reactor depressurization followed by five minutes of automatic low pressure core injection.	N/A - Enhancement due to procedure revisions are not applicable to the design certification stage of plant development.
136	Install motor generator set trip breakers in control room.	Reduced frequency of core damage due to an ATWS.	Excessive Imp. Cost – ATWS events contribute less than five four percent to overall risk. Based on the potential benefits of eliminating all offsite consequences and all core damage from ATWS sequences, the cost of this item would greatly exceed the potential benefit.

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SAMA ID (NEI-05-01)	Potential Enhancement (SAMA Title)	Result of Potential Enhancement	Qualitative Screening
Improvements Related to ATWS			
137	Provide capability to remove power from the bus powering the control rods.	Decreased time required to insert control rods if the reactor trip breakers fail (during a loss of feedwater ATWS which has rapid pressure excursion).	N/A - Enhancement due to procedure revisions are not applicable to the design certification stage of plant development.
Improvements Related to Internal Flooding			
138	Improve inspection of rubber expansion joints on main condenser.	Reduced frequency of internal flooding due to failure of circulating water system expansion joints.	N/A - Enhancement due to procedure revisions are not applicable to the design certification stage of plant development.
139	Modify swing direction of doors separating turbine building basement from areas containing safeguards equipment.	Prevents flood propagation.	N/A – this item is related to a specific issue at a specific plant. Door opening direction must be evaluated on a plant-specific basis for flooding effects.
Improvements to Reduce Seismic Risk			
140	Increase seismic ruggedness of plant components.	Increased availability of necessary plant equipment during and after seismic events.	N/A – this is a COL applicant issue.
141	Provide additional restraints for CO2 tanks.	Increased availability of fire protection given a seismic event.	N/A – this is a COL applicant issue.

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SAMA ID (NEI-05-01)	Potential Enhancement (SAMA Title)	Result of Potential Enhancement	Qualitative Screening
Improvements to Reduce Fire Risk			
142	Replace mercury switches in fire protection system.	Decreased probability of spurious fire suppression system actuation.	Effectively implemented – the fire PRA identified no significant adverse consequences for fire suppression system actuation.
143	Upgrade fire compartment barriers.	Decreased consequences of a fire.	Effectively implemented – the fire PRA identified no significant adverse consequences for fire barrier failure.
144	Install additional transfer and isolation switches.	Reduced number of spurious actuations during a fire.	Effectively implemented – the fire PRA identified no significant adverse consequences for spurious equipment actuation.
145	Enhance fire brigade awareness.	Decreased consequences of a fire.	N/A - Enhancement due to procedures/training are not applicable to the design certification stage of plant development.
146	Enhance control of combustibles and ignition sources.	Decreased fire frequency and consequences.	N/A - Enhancement due to procedures/training are not applicable to the design certification stage of plant development.

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SAMA ID (NEI-05-01)	Potential Enhancement (SAMA Title)	Result of Potential Enhancement	Qualitative Screening
Other Improvements			
147	Install digital large break LOCA protection system.	Reduced probability of a large break LOCA (a leak before break).	Excessive Imp. Cost – large LOCA events contribute only about one percent to overall risk. Based on the potential benefits of eliminating all core damage from large LOCA sequences, the cost of this item would greatly exceed the potential benefit.
148	Enhance procedures to mitigate large break LOCA.	Reduced consequences of a large break LOCA.	N/A - Enhancement due to procedure revisions are not applicable to the design certification stage of plant development.
149	Install computer aided instrumentation system to assist the operator in assessing post-accident plant status.	Improved prevention of core melt sequences by making operator actions more reliable.	N/A - Enhancement due to procedure revisions are not applicable to the design certification stage of plant development.
150	Improve maintenance procedures.	Improved prevention of core melt sequences by increasing reliability of important equipment.	N/A - Enhancement due to procedure revisions are not applicable to the design certification stage of plant development.
151	Increase training and operating experience feedback to improve operator response.	Improved likelihood of success of operator actions taken in response to abnormal conditions.	N/A - Enhancement due to training is not applicable to the design certification stage of plant development SAMDA. (Combined into the specific operator action SAMDAs)

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SAMA ID (NEI-05-01)	Potential Enhancement (SAMA Title)	Result of Potential Enhancement	Qualitative Screening
Other Improvements			
152	Develop procedures for transportation and nearby facility accidents.	Reduced consequences of transportation and nearby facility accidents.	N/A - Enhancement due to procedure revisions are not applicable to the design certification stage of plant development.
153	Install secondary side guard pipes up to the main steam isolation valves.	Prevents secondary side depressurization should a steam line break occur upstream of the main steam isolation valves. Also guards against or prevents consequential multiple steam generator tube ruptures following a main steam line break event.	Excessive Imp. Cost – secondary line break events upstream of the MSIVVs contribute less than one percent to overall risk. Based on the potential benefits of eliminating all core damage from large these events, the cost of this item would greatly exceed the potential benefit.