Entergy

Entergy Operations, Inc.
1448 S.R. 333
Russellville, AR 72802
Tel 501 858 5000

2CAN040402

April 23, 2004

U.S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, DC 20555-0001

Subject: Request for Additional Information Responses for
Environmental Report TAC No. MB8405
Arkansas Nuclear One – Unit 2
Docket No. 50-368
License No. NPF-6

Dear Sir or Madam:

By letter dated February 24, 2004 (2CNA020403), the NRC requested additional information on the Arkansas Nuclear One, Unit 2 (ANO-2) License Renewal Application Environmental Report (ER) within 60 days. The requests for additional information (RAIs) are related to the severe accident mitigation alternatives (SAMAs). The responses to the RAIs are contained in the attachment.

There are no new commitments contained in this submittal. Should you have any questions concerning this submittal, please contact Ms. Natalie Mosher at (479) 858-4635.

I declare under penalty of perjury that the foregoing is true and correct. Executed on April 23, 2004.

Sincerely,

Timothy G. Mitchell
Director, Nuclear Safety Assurance

TGM/nbm

Attachment

A100

cc: Dr. Bruce S. Mallett
Regional Administrator
U. S. Nuclear Regulatory Commission
Region IV
611 Ryan Plaza Drive, Suite 400
Arlington, TX 76011-8064

NRC Senior Resident Inspector
Arkansas Nuclear One
P.O. Box 310
London, AR 72847

U. S. Nuclear Regulatory Commission
Attn: Mr. Tom Alexion
Mail Stop 0-7 D1
Washington, DC 20555-0001

U. S. Nuclear Regulatory Commission
Attn: Mr. Greg Suber
Mail Stop 0-11 F1
Washington, DC 20555-0001

Mr. Bernard R. Bevill
Director, Division of Radiation
Control and Emergency Management
Arkansas Department of Health
4815 West Markham Street, Slot 30
Little Rock, AR 72205-3867

Attachment to

2CAN040402

SAMA RAI Responses

RAI 1:
The SAMA analysis is based on the most recent version of the ANO-2 Probabilistic Safety Assessment (PSA) for internal events, i.e., Revision 3p2, which is a modification to the Individual Plant Examination (IPE) submittal transmitted to the NRC in March 1994. Please provide the following information regarding this PSA model:

a. A description of the internal and external peer reviews of the level 1 and 2 portions of the PSA that have been performed since the IPE.

b. A description of the overall findings of the owner's group peer review (by element), and discussion of any findings/observations (e.g., A and B Facts and Observations (F&Os)) that could potentially affect the SAMA identification and evaluation process, and how Entergy has addressed these findings for this application (including, for example, sensitivity studies of the impacts of alternative assumptions).

c. A breakdown of the internal events core damage frequency (CDF) by major contributors, initiators or accident classes, such as loss of offsite power (LOOP), station blackout (SBO), transients, anticipated transient without scram (ATWS), loss-of-coolant accident (LOCA), interfacing systems LOCA (ISLOCA), steam generator tube rupture (SGTR), internal floods, etc. According to the ER Table 4-4, the staff has calculated the following:

Transients	3.90E-6
Small Break LOCA	1.52E-6
ISLOCA	3.27E-7
Vessel Rupture	2.70E-7
Medium Break LOCA	1.66E-7
Large Break LOCA	2.25E-7
SGTR	1.03E-7
Total CDF	6.51E-6

The total CDF calculated by the staff does not equate to the CDF of 7.17E-06/year calculated and used by Entergy in the SAMA analysis. It appears that ATWS and internal flooding are not included in the CDF results displayed in the ER Table 4-4. This might explain the difference in CDF values given by Entergy and calculated by the staff. Please update/revise the numbers as appropriate, and explain any differences. If ATWS and internal floods are not included, provide justification for their exclusion.

d. The approximate CDF and large early release frequency (LERF) for each revision to the PSA model, and a description of the major reasons for the changes from the prior version, i.e., a brief statement about major hardware and/or modeling changes that resulted in the new CDF.

e. The changes in the level 2 methodology since the IPE submittal, including major modeling assumptions, containment event tree (CET) structure, and binning of end states.

f. A description of the mapping of Level 1 results into the various containment end states/release categories. If this remains unchanged since the IPE, please indicate so.

g. Table E.1-2 lists the release category frequencies and fission product release fractions used in the level 3 analysis. These appear to be unchanged since the IPE submittal. If this is the case, explain why the current CDF was not used in the SAMA analysis. If not, please provide the updated values used in the level 3 analysis.

h. A breakdown of the population dose (person-rem per year within 50 miles) by containment release mode, such as steam generator tube rupture (SGTR), ISLOCA, early containment failure, late containment failure, and no containment failure.

<u>Response:</u>

1.a. The ANO-2 Individual Plant Examination (IPE) model was developed by Entergy personnel with support from Science Applications International Corporation (SAIC), now Data Systems & Solutions (DS&S). As part of the IPE development, an expert panel review was performed on the results. In addition, Engineering and Research, Incorporated (ERIN) performed an independent review of the IPE model and results. The ANO-2 PSA model has been updated several times since completion of the IPE to maintain it consistent with the as-built plant, to incorporate improved thermal hydraulic results, and to incorporate PSA improvements. The updates have involved a cooperative effort including both licensee personnel and PSA consultant support. In each of the updates, an independent review of revisions to the PSA model is performed. The PSA model and results have been maintained as plant calculations or engineering reports. As part of each major update, in order to ensure adequacy of the updated model, an expert panel reviews the PSA model results. The panel is typically composed of experienced personnel from various plant organizations, including Operations, System Engineering, Design Engineering, Safety Analysis, and PSA.

The Combustion Engineering Owner's Group (CEOG) conducted a peer review of the ANO-2 model in February 2002. The results of this review are described further in the next sub-response.

In addition, the Nuclear Regulatory Commission (NRC) Staff reviewed results of the prior version of the ANO-2 PSA model as part of the benchmarking of the ANO-2 Significance Determination Program Notebook. The Staff and its contractors conducted the review at the ANO site during November 2001. The Staff further reviewed the model, primarily the human reliability analysis and fire risk analysis, as part of its review of the risk impact of the ANO-2 extended power uprate. This review included a site visit in December 2001.

1.b. A CEOG PSA peer review, modeled after the industry peer review process in Nuclear Energy Institute report NEI 00-02, *Probabilistic Risk Assessment (PRA) Peer Review Process Guidance*, was conducted on the ANO-2 PSA. Table 1.b, attached, includes a description of the overall findings of the owner's group peer review for each element of the model.

The CEOG PSA peer review report identified five F&O in the ANO-2 PSA model with an "A" level of significance. The impact of each of the five "A" level F&O on the SAMA analysis is assessed below.

<u>F&O-A.1</u> "A" Level F&O AS-01 (accident sequence element) relates to an improper model relationship between loss of service water (SW) initiators and test and maintenance events removing pumps from service.

The PSA model used for the SAMA analysis was the most recent internal events risk model (Revision 3p2), which is an updated version of the IPE. This version of the model addressed asymmetry issues associated with removing SW pumps from service.

Since resolution of this F&O was included in the model used for the SAMA analysis, it does not affect SAMA identification or evaluation.

<u>F&O-A.2</u> "A" Level F&O AS-02 (accident sequence element) questions some events assumed to challenge primary safety relief valves.

The PSA Model used for the SAMA analysis was the most recent internal events risk model (Revision 3p2), which is an updated version of the IPE. In this version of the model, the list of events that challenge primary safety relief valves was changed assuming a realistic set of challenges.

Since resolution of this F&O was included in the model used for the SAMA analysis, it does not affect SAMA identification or evaluation.

<u>F&O-A.3</u> "A" Level F&O AS-03 (accident sequence element) questions the validity of cutsets containing loss of a 480VAC bus and failure to transfer battery charger power to another source.

The PSA Model used for the SAMA analysis was the most recent internal events risk model (Revision 3p2), which is an updated version of the IPE. In this version of the model, the fault tree logic was revised to correctly account for plant risk associated with powering 2RS-1 via swing inverter 2Y-1113 and with powering 2RS-2 via swing inverter 2Y-2224.

Since resolution of this F&O was included in the model used for the SAMA analysis, it does not affect SAMA identification or evaluation.

F&O-A.4 "A" level F&O SY-02 (system analysis element) comprises four common cause failure (CCF) issues. Since resolution of this F&O was not included in the model used for the SAMA analysis, the effect of each of these issues on SAMA identification and evaluation is assessed below:

a) A common cause failure (CCF) event affecting all three emergency feedwater (EFW) and auxiliary feedwater (AFW) pumps (i.e., turbine driven EFW pump 2P-7A, motor driven EFW pump 2P-7B, and motor driven AFW pump 2P-75) was not included in the ANO-2 PSA model.

   Sensitivity analysis shows that adding a CCF event affecting all three EFW/AFW pumps would not change the importance measures enough to significantly impact SAMA identification.

   Sensitivity analysis estimates the benefit for SAMAs FW-13 and HV-05 to be $111,000 with this portion of the F&O incorporated in the model. This is only slightly larger than the $104,000 reported in the SAMA analysis. The cost estimates for FW-13 and HV-05 are $271,000 and $226,000, respectively. Since the benefit remains less than the cost, the conclusion that these SAMAs are not cost beneficial is unchanged with the addition of a CCF event affecting all three EFW/AFW pumps.

b) A CCF event affecting AC-powered and DC-powered EFW injection valves was not included in the ANO-2 PSA model.

   Since the only shared dependency between the valves is the operators and this element has not historically been a large contributor to the failure of these valves, this CCF event would be small. Thus, the effect of adding this issue to the model is expected to be comparable to that of the three-pump CCF discussed above. Therefore, the conclusion that the SAMAs are not cost beneficial is unchanged with the addition of a CCF event affecting AC and DC EFW valves.

c) A CCF event affecting AC and DC motor operated valves (MOVs) used for emergency core cooling system (ECCS) vent valves and low temperature, overpressure protection (LTOP) valves was not included in the ANO-2 PSA model.

   Sensitivity analysis shows that adding a CCF event affecting AC and DC ECCS vent valves and LTOP valves would not change the importance measures enough to significantly impact SAMA identification.

   Sensitivity analysis shows that with the addition of a CCF event affecting AC and DC ECCS vent valves and LTOP valves, the conclusion that the SAMAs are not cost beneficial is unchanged.

d) CCF events HCC2SUCKVCCF (CCF of 2 of 2 high pressure safety injection (HPSI) suction flow path check valves to open) and HCC2HRWTCV (CCF of 2 of 2 HPSI refueling water tank (RWT) suction flow path check valves to open) appear to have been erroneously assumed to be interchangeable.

CCF events HCC2SUCKVCCF and HCC2HRWTCV were not used interchangeably. Consistent with its description, HCC2HRWTCV was used to account for CCF associated with RWT suction check valves. As there are no equivalent check valves on the containment sump suction flowpath, HCC2SUCKVCCF was not needed and was not used in the model. Therefore, this CCF event would not affect SAMA identification or evaluation.

<u>F&O-A.5</u> "A" level F&O QU-01 (quantification element) relates to the application and value of recovery action YHF2CSSUMP (failure to recover sump suction valves 2CV-5649-1 and 2CV-5650-2). Since resolution of the F&O was not included in the model used for the SAMA analysis, its effect on SAMA identification and evaluation was assessed.

A sensitivity analysis was performed in which the model was changed to conservatively account for failure to recover the sump suction valves. The analysis showed that SAMA CC-20, making containment sump recirculation outlet motor-operated valves 2CV-5649-1 and 2CV-5650-2 diverse from one another by replacing one of them with an air-operated valve, may be cost-beneficial. As this SAMA does not relate to adequately managing the effects of aging during the period of extended operation, it need not be implemented as part of license renewal pursuant to 10CFR54.

The CEOG PSA peer review report identified 30 F&Os in the ANO-2 PSA model with a "B" level of significance."

"B" level F&Os had been incorporated in the model used for the SAMA analysis, were administrative in nature, were enhancements, or were of such low significance as to have negligible impact on conclusions of the SAMA analysis.

1.c. Table 4-4 of the ER lists the ANO-2 PSA model CDF results by accident sequence from the Level 1 model (Revision 3p2) as described in section 4.20.5.1.1.

The CET branching logic from the IPE was used in the form of Level 2 top logic, combining the Level 1 and containment safeguards systems fault trees. This fault tree linking method resolves dependencies that occurred in the IPE between containment safeguards system failures and core damage sequence failures. The combined sequences were then mapped to plant damage states (PDSs). Since PDSs occur in which one or more of the containment safeguards systems are successful, each of the core damage sequences may contribute to more than one PDS. Thus, the sum of the CDF in the PDSs is slightly higher than the CDF from the Level 1 logic alone. This conservatism arises from the fact that PDS sequences include sequences that are non-minimal with respect to core damage (that is, additional failures occur to produce off-site consequences).

Therefore, the total of the values in Table 4-4 of the ER (6.51E06/yr) is slightly less than the 7.17E-06/yr value used for the baseline risk in the SAMA analysis. The following table breaks down the baseline risk in the SAMA analysis by major contributors:

Contributor	Core Damage Frequency (/yr)
transients	4.212E-06
small break LOCA	1.736E-06
ISLOCA	3.270E-07
vessel rupture	2.714E-07
medium break LOCA	1.917E-07
large break LOCA	2.805E-07
SGTR	1.446E-07
Total	7.163E-06 (rounded to 7.17E-06 for SAMA benefit comparisons)

As explained above, this difference is not due to ATWS or internal floods.

ATWS is not included in the Level 1 internal events model used for the SAMA analysis. ANO-2 performed a scoping level analysis of the ATWS event as part of the ANO-2 IPE submitted to the NRC Staff by letter dated August 28, 1992 (2CAN089201). The ATWS CDF estimate was subsequently updated. The ATWS scoping analysis is considered qualitative since it is relatively simplistic and not based on comprehensive and detailed fault tree/event tree models. The intent of the ATWS scoping analysis was to provide an order-of-magnitude assessment of the ATWS risk. The nominal ATWS CDF is estimated to be 1.59E-06/rx-yr, which was reported to the Staff by letter dated May 22, 2003 (2CAN050303). SAMAs that affect ATWS sequences were evaluated by comparing their estimated cost with double the benefit resulting from the change to CDF if core damage from an ATWS, or from failure of the charging pumps, was eliminated entirely by the proposed modification. This value was estimated by multiplying the ratio of the change in ATWS CDF to total baseline CDF by the maximum benefit attainable by eliminating the baseline CDF.

Internal floods are not included in the Level 1 internal events model used for the SAMA analysis. ANO-2 performed a scoping level analysis of internal floods as part of the ANO-2 IPE submitted to the NRC Staff by letter dated August 28, 1992. This analysis ensured that the CDF due to internal floods is less than 1E-06 for all plant zones, but did not calculate an actual CDF for internal floods. The internal flood scoping analysis is qualitative since it is relatively simplistic and not based on comprehensive and detailed fault tree/event tree models. Based upon the results of this study, the CDF contribution of internal floods was considered small enough to be covered by conservatisms in the SAMA analysis.

1.d. NRC Staff has reviewed several revisions of the ANO-2 PSA model since the IPE submittal in March 1994.

As noted in the response to question 1.a., the NRC Staff reviewed results of the prior version of the ANO-2 PSA model as part of the benchmarking of the ANO-2 Significance Determination Program Notebook. The Staff and its contractors conducted the review at the ANO site during November 2001. The Staff further reviewed the model, primarily the human reliability analysis and fire risk analysis, as part of its review of the risk impact of the ANO-2 extended power uprate. This review included a site visit in December 2001. For this version of the model (revision 2), the nominal internal event CDF of 1.70E-05/rx-yr and LERF of 3.872E-07/rx-yr were reported to the staff in a letter dated July 24, 2001 (2CAN070105).

The version of the model reviewed in the CEOG PSA peer review discussed in the response to question 1.b (revision 3p0) included revisions to account for power uprate, plant changes between 1993 and 2000, and enhanced methods for handling common cause and human failures. The nominal internal event CDF of revision 3p0 was 1.101E-05/rx-yr (LERF was not updated).

The next revision (3p1), added reactor vessel rupture as an initiator and added steam line break outside the main steam isolation valves (MSIVs) as a contributor to failure of component cooling water (CCW). It also removed loss of SW initiators from the list of initiators that challenge the primary safety relief valves. For revision 3p1, the nominal internal event CDF of 8.3E-6/rx-yr and LERF of 9.0E-7/rx-yr were provided to the Staff in support of the license amendment for extension of emergency diesel generator allowable outage time (2CAN010303 dated January 8, 2003).

Another revision of the PSA model occurred between the request for license amendment for extension of emergency diesel generator allowable outage time and the SAMA analysis. The model used for the SAMA analysis (3p2) has nominal internal events CDF of 6.183E-6/rx-yr (LERF was not updated).

Major changes in this revision of the model were:

- Addressed asymmetry issues associated with removing each of the SW pumps from service (ANO-2 PSA peer review report "A" Level F&O AS-01)
- Updated events that challenge primary safety relief valves assuming a realistic set of challenges (ANO-2 PSA peer review report "A" Level F&O AS-02)
- Revised fault tree logic to correctly account for plant risk associated with powering 2RS-1 via swing inverter 2Y-1113 and with powering 2RS-2 via swing inverter 2Y-2224 (ANO-2 PSA peer review report "A" Level F&O AS-03)
- Revised modeling for SW flow diversion to component cooling water
- Modeled procedure change associated with fast transfer of startup transformer # 2 to 2A1

1.e. For the SAMA evaluation, the CET branching logic from the IPE was used in the form of Level 2 top logic, combining the Level 1 and containment safeguards systems fault trees. This fault tree linking method resolves dependencies that occurred in the IPE between containment safeguards system failures and core damage sequence failures. The combined sequences were then mapped to PDSs, using the same method employed in the IPE.

1.f. Mapping of Level 1 results into various release categories remains unchanged since the IPE.

1.g. The information in Table E.1-2, ANO-2 Release Fraction by Nuclide Group, was copied from the IPE submittal to show the release fractions assigned to each of the nuclide groups, as described in paragraph E.1.2.2, Source Terms. The non-containment failure release modes were truncated because they do not have release fractions. The release frequencies in the table are those from the IPE submittal. The release frequencies for the baseline in the SAMA analysis are included in Table 1.g, attached.

1.h. As noted in Table E.1-6 of the ER, the total population dose for the base case is 1.723 person-rem per year within 50 miles. A breakdown of this value by containment release mode is provided in the following table:

Containment Release Mode	Population Dose (person-rem per year within 50 miles)
SGTR	0.741
ISLOCA	0.006
early containment failure	0.247
late containment failure	0.729
no containment failure	0.000
TOTAL	1.723

<u>RAI 2:</u>
Discuss the RCP seal LOCA model utilized in the ANO-2 PSA and why it is judged to provide an appropriate representation of RCP seal LOCA events. Also, indicate the current percent contribution to the CDF for RCP seal LOCA.

<u>Response:</u>
The RCP seal LOCA model in the ANO-2 PSA is based on the method described in Combustion Engineering (CE) report NPSD-755, Rev. 01. It is appropriate for the ANO-2 Byron-Jackson N-9000 RCP seal design. An updated version of this method is documented in CE NPSD-1199. The latter report incorporated Staff comments on the former. Although the ANO-2 PSA model employs the CE NPSD-755 RCP seal failure model, the RCP failure probability assumed in the ANO-2 model is conservative with respect to that of the CE NPSD-1199 model. The CE RCP seal failure model was developed as an alternative to the "Rhodes" RCP seal failure model. The Rhodes model, developed and applied to Westinghouse RCP seals, does not apply to CE RCP seals due to differences between the Westinghouse and CE RCP seal design, construction, and materials. Thus, the current model conservatively bounds the risk associated with RCP seal failure. This information was provided to the Staff in a letter dated January 8, 2003 (2CAN010303).

The percent contribution to CDF from RCP seal LOCA is approximately 9.87%.

<u>RAI 3:</u>
Based on the accident sequence descriptions provided in the ER, it does not appear that thermally-induced SGTR is included in the level 1 PSA model. Discuss the impact of including thermally-induced SGTR events on the SAMA analysis.

<u>Response:</u>
Temperature induced SGTRs (TI-SGTR) are SGTRs caused by heating of steam generator tubes by hot gases released from a damaged core. The likelihood of a TI-SGTR depends on both plant design and on accident conditions. Since severe accident conditions must exist for a TI-SGTR event, TI-SGTR does not increase CDF. Rather, TI-SGTR affects the likelihood and magnitude of fission product release to the environment during a severe accident by creating a release path from the reactor coolant system to the secondary plant through a damaged tube. Since level 1 PSA models include only events resulting in core damage, TI-SGTR cannot be included in a level 1 PSA model.

TI-SGTR affect on the likelihood and magnitude of fission product release to the environment during a severe accident was not considered in the SAMA analysis and would have negligible impact on the SAMA analysis if included. The probability of TI-SGTR is directly related to steam generator tube defects. New steam generators were installed in ANO-2 during the 2R14 refueling outage (Fall of 2000) making the probability of TI-SGTR negligible.

In addition, several SAMAs were evaluated that would increase reliability of steam generator cooling, thereby decreasing the potential for TI-SGTR. For example, SAMA FW-08 recommends using portable generators to power the turbine-driven auxiliary feedwater pump controls after station batteries are depleted. SAMA FW-13 recommends installing an independent diesel for the condensate storage tank makeup pumps to allow for continuous makeup to the condensate storage tank during an SBO event. SAMA FW-15 recommends adding a passive, secondary-side heat-rejection loop consisting of a condenser and heat sink. Also, procedural enhancements to ensure reliability of cooling were evaluated in SAMA FW-17.

<u>RAI 4:</u>
Relative to the MACCS2 input and results, please provide the following:

a. A brief discussion on how the releases were modeled, e.g., at ground level with a thermal content the same as ambient, and

b. Clarification of whether the replacement power costs were scaled relative to the 910 MWe reference plant since ANO-2 is rated at 1023 MWe.

Response:

4.a. Release category characteristics (e.g., height of release, energy of release) were assigned by analogy with the source terms reported for Surry in the NUREG-1150 study that were judged, based on descriptions, to be similar in character to the various ANO-2 release modes. Parameter values used, as a function of containment failure mode, are provided in the following table.

(PLHITE is the height of release, and PLHEAT is the energy of release.)

MACCS2 Timing Parameters for Containment Failure Modes

MACCS2 Parameters	Early-Rupture	Early-Leaks	Bypass	Late
PLHEAT (w)	2.1E+06	1.8E+06	1.0E+06	9.2E+05
PLHITE (m)	30	30	30	30

4.b. The characteristic power output for the generic reactor cited in NUREG/BR-0184 was used when calculating replacement power cost. This value was not scaled relative to the reference plant. Sensitivity analysis shows that if replacement power costs were increased by 12%, there would be only a slight increase in the estimated benefit for each SAMA case and there would be no impact on the conclusions drawn during the SAMA analysis.

RAI 5:

According to the ER, Entergy evaluated 192 SAMA candidates and eliminated 99 SAMAs during the initial screening. In this regard, please provide the following:

a. A description of how the dominant risk contributors at ANO-2, including dominant sequences and equipment failures and operator actions identified through importance analyses (e.g., Fussell-Vesely, Risk Reduction Worth, etc.) were used to identify potential plant-specific SAMAs.

b. The percentage of the total CDF represented by the top 100 cut sets that were evaluated.

c. A listing of equipment failures and human actions that have greatest potential for reducing risk at ANO-2 based on importance analysis and cut set screening.

d. For each dominant contributor identified in the current PSA, a cross-reference to the SAMA(s) evaluated in the ER that address that contributor. If a SAMA was not evaluated for a dominant risk contributor, justify why SAMAs to further reduce these contributors would not be cost beneficial.

e. A list of the 99 SAMAs that were screened out in the initial screening and the basis for excluding each of these SAMAs.

f. The status of each of the SAMA candidates obtained from the Individual Plant Examination of External Events (IPEEE) (SAMAs IPEEE-01 through IPEEE-11), and

g. By letter dated October 5, 1995, Entergy indicated that SAMA FW-17 was implemented in 1993. In addition, the staff understood that SAMA CB-23 was implemented. However, these enhancements are evaluated in the SAMA analysis and found to not be cost beneficial. Confirm whether these enhancements were actually implemented.

<u>Response:</u>

5.a. Importance measures were not used to identify potential SAMAs, rather dominant risk contributors and plant-specific design modifications derived directly from the PSA were identified and postulated through review of the top 100 cut sets. Specifically, from the PSA master model, the top 100 cut sets were reviewed for failures that could be addressed through an enhancement to the plant. For these failures, either similar modifications considered at other plants were identified as plant-specific candidates or new modifications were postulated to address the risk contribution from a particular cut set (or collection of cut sets).

Nevertheless, a list of dominant equipment failures and operator actions, based on importance measures, is provided and discussed in the responses to Parts c and d of this question.

5.b. The top 100 cut sets represent approximately 62% of the total CDF.

5.c. As was discussed in Part a of this question, the dominant risk contributors were identified using the top 100 cut sets as the basis for postulating plant-specific design modifications. Nonetheless, a listing of failures, with their associated risk achievement worth (RAW) and Fussell-Vesely (F-V) importance measures, is provided as Table 5.c. Failures modeled by the ANO-2 PSA were assessed to establish the risk-significance of each failure based on the combined effect of its F-V and RAW. Failures with RAW > 2 and F-V > 0.001 were identified as the most important failures and are represented in Table 5.c, attached.

Important failures based on cut set screening were discussed in the response to Part (a) of this question. These failures are also listed in Table 5.c. If a failure from the cut set screening was not already in the table due to its F-V and RAW, the values in these fields are outside the limits defined above.

5.d. For each dominant contributor, a cross-reference to the SAMA(s) evaluated is provided in Table 5.c.

Table 5.d lists the dominant contributors without a corresponding SAMA. Screening analysis was performed to estimate the benefit of completely eliminating each of these failures. Table 5.d is sorted by the failures that have the greatest benefit associated with their elimination.

The cost of modifying a single procedure is $35,000. This value represents a reasonable lower bound to assess the cost-effectiveness of potential modifications at ANO-2, since most modifications would require procedure changes in addition to hardware modifications. Therefore, SAMAs to further reduce the contribution from failures in Table 5.d with a potential benefit less than $35,000 would not be cost beneficial.

The three failures in Table 5.d whose elimination results in a potential benefit greater than $35,000 are discussed below.

<u>1 of 2 safety relief valves (SRVs) failing to re-close after pressure relief</u>
(Estimated benefit of elimination of this failure is $117,400)

ANO-2 does not have pilot-operated relief valves (PORVs) with associated block valves. Pressure relief is accomplished via two code SRVs. Replacing the SRVs with a more reliable valve would not eliminate the potential for failure and consequently would have minimal benefit. A modification to add PORVs with block valves for pressure relief during an overpressure transient would result in significant cost (>$117,400) including hardware, installation, procedural and analytical costs. Therefore, SAMAs to reduce the potential for SRV failure would not be cost beneficial.

<u>Loss of Condenser Vacuum</u>
(Estimated benefit of elimination of this failure is $58,200)

Loss of condenser vacuum is an initiating event that requires a combination of other failures to result in an adverse end state. Modifications to significantly reduce or eliminate the potential for loss of condenser vacuum, such as adding an additional vacuum pump, increasing reliability of vacuum pumps 2C-5A and 2C-5B, or other hardware modification would cost more than $58,200. Enhancement of the loss of condenser vacuum procedure would not affect the risk contribution of this initiating event. Therefore, SAMAs to further reduce this contributor would not be cost beneficial.

<u>Reactor Trip Initiating Event</u>
(Estimated benefit of elimination of this failure is $36,000)

Reactor trip is an initiating event that requires a combination of other failures to result in an adverse end state. Modifications to significantly reduce or eliminate the potential for spurious reactor trip, such as upgrading the reactor protection system, would cost far more than $36,000. Enhancement of the reactor trip recovery procedure would not directly affect the risk contribution of this initiating event. Therefore, SAMAs to further reduce reactor trip frequency would not be cost beneficial. In summary, SAMAs to further reduce the dominant risk contributors in Table 5.d would not be cost beneficial.

5.e. As described in Section 3.2.2 of the ER, 99 SAMA candidates were screened out in the initial screening. Of the 99 excluded candidates, 40 were screened out because they modified features not applicable to ANO-2, 47 had already been implemented at ANO-2, and 12 were a duplicate of another SAMA candidate. The list of 99 excluded candidates is available in on-site documentation.

5.f. SAMA candidates obtained from the IPEEE were eliminated from further consideration during the preliminary screening because they have already been implemented. Completion of these actions was reported to the Staff in a letter dated November 18, 1999 (0CAN119901).

5.g. Potential improvement 6.2.1.4 from the IPE (SAMA FW-17) was implemented February 15, 1993, and potential improvement 6.2.1.3 from the IPE (SAMA CB-23) was implemented March 3, 1993. Completion of these actions was reported to the Staff in a letter dated October 5, 1995 (2CAN109502).

RAI 6:

The SAMA analysis did not include an assessment of SAMAs for external events. The ANO-2 IPE for External Events (IPEEE) SER reports that the CDF due to internal fire initiated events is about $3.8x10^{-5}$ per reactor year which is substantially greater than the internal events CDF on which the SAMA evaluation is based. The risk analyses at other commercial nuclear power plants also indicate that external events could be large contributors to CDF and the overall risk to the public. In this regard, the following additional information is requested:

a. NUREG-1742 ("Perspectives Gained From the IPEEE Program," Final Report, 4/02), lists the significant fire area CDFs for ANO-2 (page 3-8 of Volume 2). While these fire-related CDF estimates may be conservative, they are still large relative to the ANO-2 internal events CDF. For each fire area, please explain what measures were taken to further reduce risk, and explain why these CDFs can not be further reduced in a cost effective manner.

b. NUREG-1742 lists seismic outliers and improvements for ANO-2 (page 2-25 of Volume 2). Indicate whether the "Plant improvements" that address the outliers have been implemented for all outliers. If not, please explain why within the context of this SAMA study.

Response:

6.a. Significant fire areas are equipped with a detection system that alarms in the control room. Also, several zones are equipped with an automatic suppression system. Therefore, no cost-effective hardware changes were identified to reduce CDF in these areas.

The Fire Protection Program uses a three-tiered approach:

Preventing fires from starting.

Detecting fires promptly, suppressing them quickly, and thereby limiting fire damage.

Designing plant safety systems so that a fire which does start will not ultimately prevent essential plant safety functions from being accomplished.

During higher risk evolutions, risk sensitive fire areas are subject to more stringent controls. For example, during EDG outages, ANO controls welding and transient combustibles in the transformer yard, south switchgear room, cable spreading room, intake structure, diesel corridor, lower south electrical/piping penetration room, electrical equipment room and in the vicinity of the turbine building switchgear. During EDG outages, ANO also establishes continuous fire watches in the vicinity of the turbine building switchgear and confirms operability of fire suppression in the transformer yard.

Following the ANO-2 Fire Hazards Analysis provisions and procedures provides assurance that risk in these areas is minimized. Therefore, no cost-effective procedural changes were identified to reduce CDF in these areas.

6.b. The outliers for ANO-2 have been resolved in accordance with the proposed resolutions in Table 7.1 of the summary report of IPEEE for ANO-2 (Letter 0CAN059609 dated May 31, 1996). This information was provided to the Staff in a letter dated March 30, 1999 (0CAN039901). Specifically, the second paragraph on page 21 of the attachment to this letter states, "For ANO-2, the outliers listed in table 7-1 have been resolved." In addition, a completion letter dated November 18, 1999 (0CAN119901), was provided to the NRC advising the Staff that corrective actions identified in the ANO summary reports, or agreed to with the Staff as a result of other related correspondence, had been completed.

<u>RAI 7:</u>
Entergy has opted to double the estimated benefits (for internal events) to accommodate any contributions for external events. This is acceptable when sound reasons exist to support such a numerical adjustment. However, based on the information in the ER and in the ANO-2 IPEEE report, the fire CDF is approximately a factor five greater than the internal events CDF, which suggests that the estimated benefit for the SAMAs should be increased by at least a factor of six to account for external events (in contrast to the factor of two used in the SAMA analysis). In order to determine if external events have been satisfactorily accounted for, please provide the following information:

a. The current CDF for fire-initiated events, and justification that doubling the estimated benefits for internal events will bound the risk from fire events.

b. An assessment of the impact on the initial and the final screenings if the internal events risk reduction estimates are increased by a factor that would bound the risk from fire and seismic events, and

c. Justification for why the following SAMAs would not be cost beneficial when the risk reduction associated with external events is reflected in the baseline estimates, given that the implementation costs are within a factor of 3 of the estimated benefits: AC/DC-16, AT-02, CB-10, CB-26, CC-07, CW-06, CW-21, CW-23, CW-27, EV-02, FW-13, FW-17, HV-03, HV-05, and OT-06.

<u>Response:</u>
7.a. A single CDF associated with fires is not calculated in the ANO-2 Fire Analysis. Because the fire analysis is a screening analysis, fire zone CDF values are conservatively high estimates.

In the latest fire analysis, the unscreened fire zones and associated CDF values are as shown in the following table.

Fire Zone	Description	Average CDF
N/A	Transformer Yard	1.09E-06
B3SC	Aux Bldg Ext	1.22E-06
2097-X	East DC Equip Room	1.73E-06
2096-M	MCC2B63 Room	1.75E-06
2098-C	New CPC Room	1.79E-06
2199-G	Control Room	1.90E-06
2063SC	Aux Bldg el. 354'	1.93E-06
2101-AA	North Switchgear Room	2.28E-06
2100-Z	South Switchgear Room	3.72E-06
2055SC	Lower South Elect/Piping Penet Rm	5.18E-06
2108-S	Electrical Equipment Room	7.26E-06
2109-U	Diesel Corridor	4.87E-06
IS	Intake Structure	1.21E-05
2098-L	Cable Spreading Room	1.61E-05
B5	Turbine Bldg	2.00E-05

The ANO-2 Fire Analysis was performed using EPRI's Fire Induced Vulnerability Evaluation (FIVE). In this method, a fire initiating frequency is combined with a conditional core damage probability (CCDP) to determine the CDF for the zone. The CCDP for each fire zone is calculated using the Level 1 internal events PSA. This is accomplished by failing all equipment in the fire zone and solving the model for transient (turbine trip) initiated sequences. If the CDF obtained by combining this CCDP value with the zone's fire initiating frequency is less than 1.0E-06, the zone is screened from further analysis. Zones that did not screen on the first pass were evaluated to determine if conservative assumptions were made, or if operator recovery actions could be applied. The zones that did not screen on the second pass are the "unscreened zones" listed in the above table.

The unscreened zones were systematically evaluated to determine if cost-effective hardware or procedure changes could reduce risk in these areas. Evaluation determined that existing zone configurations, fire protection features and fire protection practices are sufficient to minimize risk in these areas. For example, the unscreened zones are monitored by a detection system that alarms in the control room. Additionally, several zones are equipped with an automatic suppression system. Electrical cabinets in the zones use rated cables that are difficult to ignite and slow to propagate. A radiant energy shield and suppression system prevent a fire on one SW pump motor from disabling other SW pumps. Ignition sources in the turbine building are limited and are not located close to critical components. The hot work permit program and transient combustible loading program reduce possible ignition sources. Also, the fire protection program ensures that ignition sources are limited and maximizes the availability of fire protection equipment. Therefore, existing zone configurations, fire protection features and fire protection practices minimize risk in these areas and no cost-effective hardware or procedure changes were identified to further reduce CDF in the unscreened zones.

Doubling the estimated benefits for internal events will account for the risk from fire events because of the following conservatisms.

- The fire analysis was done as a screening analysis only and not as a determination of the risk value for a fire at ANO-2. Therefore, results from the fire analysis are very conservative. Methods and technology available to perform the fire analysis have not reached the same level of maturity as those used in the internal events analysis. The fire analysis is primarily a screening study used to identify weaknesses based on relative risk. The end result identifies important components or scenarios, but does not provide a best-estimate CDF that can be compared to one developed for internal events. While the fire analysis evaluated plant strengths and weaknesses, the resultant core damage frequencies are not appropriate for comparison to core damage frequencies from the IPE.

- Since the fire zone CCDP is calculated by failing all equipment in the fire zone and solving the model for transient initiated sequences, a SAMA that reduces internal events CDF may not reduce the fire CDF for a zone. Several examples are given in the response to question 7.c.

- Since the fire zone CCDP is calculated by failing all equipment in the fire zone, rather than a rigorous analysis of possible fire-induced failure modes, the importance of those failures not caused by the fire is inflated. It is possible to apply assumptions used in a SAMA analysis case to calculation of a CCDP for a fire zone and estimate a corresponding benefit. However, the resulting benefit value is inflated and therefore overly conservative for use in SAMA evaluation.

Since the fire analysis does not provide the means to determine best-estimate numerical values for CDF contributions from fire initiators and the search for external event vulnerabilities as part of the IPEEE and subsequent fire analysis did not identify risk contributors that would benefit from potential SAMAs, doubling the estimated benefits for internal events is appropriate to account for the risk from fire events.

7.b. Increasing the risk reduction estimates would have no impact upon the initial screening of SAMA candidates because risk reduction estimates were not a factor in the initial screening. In the initial screening, potential SAMA candidates were screened out if they modified features not applicable to ANO-2, if they had already been implemented at ANO-2, or if they were similar in nature and could be combined with another SAMA candidate to develop a more comprehensive or plant-specific SAMA candidate.

As described in the responses to questions 7.a and 7.c, doubling the estimated benefits for internal events is appropriate to account for the risk from fire events. Since the risk contribution from seismic, high winds and tornadoes, external flooding, transportation and nearby facility accidents, and other external events reported in the IPEEE is relatively low, they are also accounted for by doubling. Therefore, the final screening is not impacted.

7.c. None of these 15 SAMAs relates to adequately managing the effects of aging during the period of extended operation. Therefore, they need not be implemented as part of license renewal pursuant to 10CFR54.

Also, as described in the response to question 7.a, doubling the estimated benefits for internal events is appropriate to account for the risk from fire events.

The following examples illustrate why individual SAMAs that reduce internal events CDF do not reduce the fire CDF for a zone, or only slightly reduce the fire CDF for a zone. They show that the SAMAs are not cost effective when the risk reduction associated with external events is reflected in the estimated benefit.

Similar analysis of the other SAMAs is expected to yield the same conclusion: the SAMAs are not cost effective when the risk reduction associated with external events is reflected in the baseline estimates.

SAMAs CB-10 and CB-26 recommend modifications to reduce the frequency of an ISLOCA or SGTR. In the fire analysis, a fire event is assumed to cause a transient that involves the failure of a specific set of components. None of these failures directly causes an ISLOCA or a SGTR, so these SAMAs would not reduce the CDF for any of the fire zones. Thus, the conclusion that these SAMAs are not cost effective remains valid.

SAMA EV-02 recommends installing automatic containment spray pump header throttle valves, which is an ex-vessel accident mitigation or containment performance SAMA. The CCDP for each fire zone is calculated using the Level 1 Internal Events PSA, which does not include containment performance events, so this SAMA would not reduce the CDF for any of the fire zones. Thus, the conclusion that this SAMA is not cost effective remains valid.

SAMA OT-06 recommends installing secondary side guard pipes up to the main steam isolation valves to prevent failures following a steam line break. In the fire analysis, a fire event is assumed to cause a transient that involves failure of a specific set of components. None of these failures directly causes a main steam line break, so this SAMA would not reduce the CDF for any of the fire zones. Thus, the conclusion that this SAMA is not cost effective remains valid.

RAI 8:
The SAMA analysis did not include an assessment of the impact of PSA uncertainties. On that basis, please provide the following information to address these concerns:

a. An estimate of the uncertainties associated with the calculated core damage frequency (e.g., the mean and median internal events CDF estimates and the fifth and 95th percentile values of the uncertainty distribution), and

b. An assessment of the impact on the final screening if risk reduction estimates are increased to account for uncertainties in the risk assessment. Please consider the uncertainties due to both the averted cost-risk and the cost of implementation to determine changes in the net value for these SAMAs.

Response:

8.a. CDF uncertainty values are not available for the current version of the PSA model.

8.b. A quantitative assessment of the impact on the final screening is not necessary to account for uncertainties in the risk assessment. There is sufficient conservatism throughout the SAMA analysis to account for uncertainty in the estimation of CDF. Taking into account these conservatisms, as described below, the conclusions of the SAMA analysis would not be affected.

Conservatisms in the SAMA analysis include:

- The site file (input file for MACCS2) was prepared with the population estimated for the year 2040. ANO-2's current license will expire in July 2018. Assuming a 20-year license extension is granted, the extended license will expire in July 2038. For the level 3 PSA model, the estimated population for 2040 was used. Overestimating the population is conservative because the population dose and economic impact costs are a function of population and are, therefore, larger for a larger population. Since an accident could only occur between now and 2038, the actual population is less than the estimate, and the benefit of each SAMA evaluated is overestimated.

  The method by which the 2040 population was estimated was conservative. The population in 2040 was estimated from the 2000 population (resident and transient) data. Population growth was evaluated within a 50-mile radius of the ANO site from 1990 to 2000, as well as the population growth for the state of Arkansas between those two years. Two extrapolation schemes were considered, one based on site-area population growth and one based on state population growth, as shown below.

1990	2000	factor	2010	2020	2030	2040	Comment
210198[(1)]	267664[(1)]	27.34%	340841	434023	552380	703778	% increase/decade
2350725[(2)]	2673400[(2)]	13.73%	304414	346210	393745	447806	% increase/decade

  [(1)] Resident population within 50-mile radius of ANO site
  [(2)] Resident population for the state of Arkansas

  While using percentage increase (13.73%) based on the entire state's population seems more realistic, the higher, conservative escalation rate based on the 50-mile radius population around the ANO site was used. The population escalation factor used was: 703778/267664 = 2.63. That is, the 2000 population data was multiplied by 2.63 to estimate the 2040 population (per grid sector).

- In addition to the qualitative argument that the identified conservatisms adequately account for uncertainty in the CDF, several sensitivity cases were performed on the results of the MACCS2 analysis. While there was some variability in the population dose and economic costs, it did not significantly change the results.

- The benefits of candidate SAMAs were estimated by altering the base case PSA model to reflect the maximum benefit of the improvement and recalculating the CDF. Generally, the maximum benefit of the SAMA was determined with a bounding modeling assumption. For example, if the objective of the SAMA was to reduce the likelihood of a certain failure mode, then eliminating the failure mode from the PSA bounded the benefit, even though the SAMA would *not* be 100% effective in eliminating the failure. Often the impact of a SAMA was estimated by eliminating a specific initiating event from the PSA model, although the SAMA would *not* be 100% effective in eliminating the initiating event. These bounding assumptions overestimate the value of the SAMA.

- Benefits of many of the SAMA were estimated simply as the "maximum attainable benefit", equivalent to removing all severe accident risk associated with the operation of ANO-2 (i.e., eliminating all core damage). This, as with specific PSA modifications, is conservative as the SAMAs would *not* effectively eliminate all contribution to core damage. As discussed above, the bounding assumptions overestimate, often significantly, the value of the SAMA.

- The attainable benefit was estimated over a 35-year span from 2003 until the end of a 20-year license renewal period. This is equivalent to stating that the analysis considers a severe accident to occur during 2003 (i.e., last year) with long-term costs such as replacement power compounded until the end of the license renewal period. With each passing year, the attainable benefit for each SAMA would decrease indicating that the estimated benefit for each was conservative. If an accident occurred at the midpoint of remaining asset life, e.g., at 17 years, the maximum attainable benefit (i.e., eliminating all core damage) would be $377,000, as opposed to the $632,000 used in the cost-benefit screening.

- Cost estimates for candidate SAMAs are conservative. The cost of implementation was primarily established from existing estimates of similar modifications combined with engineering judgment. Most of the cost estimates were developed from similar modifications considered in previous SAMA and severe accident mitigation design alternative (SAMDA) analyses. These implementation cost estimates are conservative for ANO-2 since no credit was taken for inflation when applying them to ANO-2 SAMAs. Further, previous cost estimates do not include costs associated with replacement power for an extended outage during implementation of the alternatives. In addition, several implementation costs were originally developed for SAMDA analyses (i.e., during the design phase of the plant) and, therefore, do not capture additional costs associated with performing design modifications to existing plants (i.e., reduced efficiency, minimizing dose, disposal of contaminated material, etc.). Therefore, the cost to implement a SAMA candidate is generally underestimated. With the benefits overestimated and the costs underestimated, the "actual" difference between cost and benefit would be greater than is shown in the SAMA analysis.

- Several sensitivity cases were performed to evaluate sensitivity of the cost-benefit estimates to various assumptions (e.g., discount rate). None of the sensitivity cases showed that the SAMA candidates were cost-beneficial.

Finally, to perform a proper uncertainty analysis, which accounts for variability in CDF, cost of alternative implementation, etc., a simulation program would have to be developed to ensure that worst cases were not routinely considered simultaneously. Inasmuch as uncertainties in the SAMA analysis are accounted for via conservatisms discussed above, performance of a quantified uncertainty analysis would require re-evaluation of the conservatisms (e.g., reviewing bounding cases for CDF estimation, reviewing assumptions in cost estimation) to avoid being overly conservative. The effort and expense to conduct such a study is not commensurate with estimated benefits of the study, i.e., conclusions of the SAMA analysis are not expected to change as a result of a quantitative analysis of uncertainty.

RAI 9:
Based on a review of Table E.2-1 of the ER, cost estimates for implementation are provided only when a previous cost estimate was available, or when the candidate SAMA involves a modification to a procedure. For the remaining SAMAs, only a generic statement is provided that the cost of implementing the SAMA is judged to exceed the attainable benefit. Please provide justification, supported by a more detailed analysis or cost estimate, for eliminating the following SAMA candidates, particularly when the risk reduction associated with external events is reflected in the baseline estimates: CB-03, CB-14, CC-01, CC-20, CW-01, CW-09, CW-13, CW-24, CW-26, EV-31, and FW-01.

Response:
For several SAMAs, detailed cost information for a similar modification available in the public domain was used. Procedure changes were compared with a generic estimate of the total cost of implementing a procedure change. SAMAs not covered by either of these methods were informally estimated to the point where it became clear that the modification would not be cost beneficial. Since the attainable benefit from implementing many of these SAMAs is very low, the need to perform a detailed documented cost estimate is unnecessary, particularly considering the conservative nature of SAMA modeling. Nonetheless, additional information regarding these particular SAMAs is provided below.

CB-03 Increase Pressure Capacity of Secondary Side
This SAMA recommends increasing the secondary side pressure capacity such that a SGTR would not cause the relief valves to lift, thus preventing a direct release pathway to the environment. The reduction in risk for this SAMA was estimated by eliminating all SGTRs from the PSA model. This resulted in an attainable benefit of $25,000. Since increasing secondary side pressure capacity would not eliminate potential for a SGTR, but would only mitigate environmental effects, the estimate of $25,000 is conservative for this SAMA. Nonetheless, increasing the pressure capacity would require extensive hardware, procedure, and analysis changes. Since the cost of modifying a procedure (with associated training) is $35,000, the total cost of increasing secondary side capacity would significantly exceed $25,000.

CB-14 Increase Frequency of Valve Leak Testing
This SAMA considered increasing leak-rate testing frequency to ensure the leak-tight nature of containment isolation valves to preclude the potential for an ISLOCA. The reduction in risk for this SAMA was estimated by removing all contribution to core damage due to an ISLOCA from the PSA model. This resulted in an attainable benefit of $86,000. Since increased inspection frequency would not eliminate the potential for an ISLOCA, the estimated benefit for this SAMA, in reality, would be lower than $86,000. Nonetheless, the cost of a single procedure change (with associated training) is estimated at $35,000. Assuming minimal increased inspection costs of $2,500 annually for the remaining 35 years of plant life, the total cost would exceed $86,000. Cost for a testing crew is on the order of $8,000 per week, for a typical duration of about three weeks.

CC-01 Provide Diesel Driven Low Pressure Vessel Makeup
This modification recommends providing a diesel driven low pressure makeup pump to maintain inventory within the reactor coolant system (RCS) if the reactor is depressurized and no other makeup sources are available. The reduction in risk for this modification was estimated by completely eliminating all core damage (due to all causes). This resulted in an attainable benefit of $632,000. Obviously, the proposed modification would not eliminate all core damage risk; therefore, the modeling assumption is conservative. A more realistic benefit estimate can be made by eliminating the potential for a large break LOCA leading to core damage. The benefit of eliminating a large break LOCA is estimated to be $24,000, thus making even the supporting procedure change not cost beneficial. Nonetheless, installing the AFW pump at ANO-2 cost approximately $3,000,000 in 1992. The cost of adding a makeup pump with an independent diesel (or similar modification) would be on the same order of magnitude, so the estimated cost of this SAMA is over the $632,000 maximum attainable benefit.

CC-20 Diversify MOVs 2CV-5649-1 and 2CV-5650-2
This SAMA considered removing MOV 2CV-5650-2 and replacing it with an air-operated valve (AOV) to preclude the potential for common-cause failure of the containment sump recirculation outlet valves. The reduction in risk for this modification was estimated by eliminating all contribution to core damage from common-cause failure of these valves. This resulted in an attainable benefit of $31,000. Replacing an MOV with an AOV would require changes to operating and maintenance procedures in addition to hardware and design costs. Since the cost estimate for a single procedure change with associated training is $35,000, the total cost of replacing MOV 2CV-5620-2 with a diverse AOV would be greater than the $31,000 benefit. However, a sensitivity analysis in which the model was corrected to more accurately account for failure to recover the sump suction valves indicates this SAMA may be cost-beneficial. See response to question 1.b. As this SAMA does not relate to adequately managing the effects of aging during the period of extended operation, it need not be implemented as part of license renewal pursuant to 10CFR54.

CW-01 Cap Downstream Piping for Drain/Vent Valves in CCW System
This modification would involve capping the piping downstream of CCW drain and vent valves or installing redundant valves in these lines to reduce the frequency of the loss of CCW initiator. Since loss of CCW is included in the loss of feedwater initiating event, a conservative risk reduction was estimated by eliminating loss of feedwater from the PSA model. This resulted in an attainable benefit of $112,000 (i.e., the realistic modeling of this modification would result in a much lower attainable benefit). There are approximately 100 drain and vent lines within the CCW system that are uncapped. Assuming $35,000 to

change the procedure (and associated training) for operation, filling and venting of the CCW system and $1000 per line for hardware and installation of a valve or removable cap, the total cost would exceed the attainable benefit.

CW-09 Provide an Additional Diverse SW Pump
This modification would involve providing an additional SW pump that is diverse from the other SW pumps to prevent common cause failure of SW pumps and increase the overall reliability of the SW system. The risk reduction for this modification was estimated by eliminating all core damage resulting from loss of SW. This resulted in an attainable benefit of $202,000. Since the suggested modification would not preclude the potential for loss of SW, the estimated attainable benefit is conservative. A recent wet end replacement on SW pump 2P-4C at ANO-2 cost approximately $265,000. Thus, the cost of procuring a SW pump, connecting it to the SW system, ensuring that it is diverse of the other pumps, modifying drawings, procedures, and analyses would cost much more than $265,000.

CW-13 Replace All ECCS Pump Motors with Air-Cooled Motors
This modification would involve providing all ECCS pumps with air-cooled motors rather than motors cooled by SW. In retrospect, this SAMA is not applicable to ANO-2 and could have been screened out since the ECCS pump motors are air cooled with only the seals and bearings cooled by SW. A more appropriate SAMA would be aimed at increasing reliability of the ECCS pump seal and bearing cooling by increasing reliability of the SW system. Several modifications (e.g. CW-09, CW-23, CW-26 and CW-27) have been evaluated that are aimed at increasing reliability of the SW system and consequently increasing reliability of seal and bearing cooling for the ECCS pumps.

CW-24 Automatically Trip RCPs on Loss of CCW
This modification would involve installing hardware to trip the RCPs in the event of a loss of CCW to eliminate the need for operator action. The risk reduction for this case was estimated by eliminating failure of the operator to trip the pumps in the event of loss of CCW (i.e., making this action perfectly reliable). This resulted in an attainable benefit of $71,000. Automating this action would not result in perfect reliability because of the potential for hardware failures. Making this modification would require changes to operating, maintenance and testing procedures in addition to hardware and design costs. Since the cost estimate for a single procedure change with associated training is $35,000, the total cost would be greater than the maximum attainable benefit, particularly considering the conservative nature of the attainable benefit.

CW-26 Increase Inspection Frequency of SW Pump Discharge Filters
This SAMA considered increasing the inspection and cleaning frequency of the SW pump discharge filters. The risk reduction for this modification was estimated by removing all contribution to core damage due to common-cause failure of these filters from the PSA model. This resulted in an attainable benefit of $100,000. Increasing the inspection frequency would not preclude the potential for common-cause failure of these filters, and therefore, the attainable benefit estimate of $100,000 is conservative. If this work is performed by one individual earning $20 per hour and takes six hours per cleaning, adding a weekly cleaning for one SW pump discharge filter would cost $6,240 per year or $218,400 from now through the end of the period of extended operation. Since ANO-2 has three SW pumps, the cost of this SAMA is well in excess of the attainable benefit.

EV-31 Remove Reactor Vessel Cavity Check Valve 2BS-46 Internals

This SAMA, originally identified in the IPE, recommends removing reactor vessel cavity check valve 2BS-46 internals to improve the potential for cooling molten core debris in the bottom of the cavity during an ex-vessel severe accident. Further evaluation revealed that this modification would increase the potential for pressurized thermal shock of the vessel during other scenarios, so it was not implemented. This modification was included in the SAMA analysis, ignoring the potential negative effects to produce a bounding estimate for determining the cost effectiveness of this modification. The risk reduction from this modification was estimated by removing all contribution from PDS IVKi. This resulted in an attainable benefit of $17,000. Since performing this modification would necessitate a procedure change in addition to unquantified costs associated with drawing and calculation revisions to address pressurized thermal shock implications, this SAMA is clearly not appropriate for implementation, particularly considering the trade off in potential safety ramifications.

FW-01 Install a Digital Feedwater Upgrade

This modification would involve installing a digital feedwater control system to reduce the likelihood of loss of main feedwater following a plant trip. In retrospect, this SAMA should have been screened out since ANO-2 installed a digital feedwater upgrade during the late 90s. Therefore, this modification is not applicable for ANO-2.

Table 1.b – Summary of ANO-2 PSA Peer Review Results

Element	Rating	Description of Overall Findings
initiating events	marginal	Marginal areas were identification and grouping of initiators and treatment of subsumed events. The power conversion initiator is used to capture less important initiators, as is typical in most PSAs. ANO-2 should strengthen documentation that subsumed events have the same impact on CDF. ANO-2 should ensure that effects of power upgrade are incorporated into applicable initiators.
accident sequence	marginal	The main area for improvement is a more detailed review of the accident sequences.
thermo-hydraulic	meets	Traceability of TH bases for success criteria and human action timing is good. Best estimate analyses are used for many success criteria and timing evaluations.
system analysis	meets	In general, system models are good. Key issues are failure to include HEP for load shedding of batteries following SBO and failing to include CCF for common elements of EFW/AFW.
data	meets	Data collection and analysis process looks good. Inclusion of control circuit failures would enhance the robustness of the overall analyses and increase the flexibility.
dependency	meets	Dependency analysis was thorough.
human reliability	meets	With a minor process improvement, treatment of human action dependency could be "Exceeds."
structural	meets	Reactor vessel rupture should be included as an initiator. Containment capability evaluation should address temperature effects for liner tear modes.
quantification	meets	Inappropriate equipment recovery actions were applied to several high level cutsets. In addition, a number of the issues identified for accident sequence evaluation also impact quantification.
level 2	meets	Level 2 analysis is thorough, but hasn't been updated since the IPE. Simplified LERF calculations are used, but the LERF definition is not fully consistent with current practices.
maintenance and update	meets	Use of the expert panel is a superior practice.

Table 1.g – Release Frequencies for the Baseline SAMA Analysis

Release Mode	Frequency (/rx-yr)
A1	9.54E-10
A2	1.97E-11
B1	6.43E-14
B2-L	3.34E-11
B2-R	1.76E-12
B3-L	3.15E-10
B3-R	3.15E-10
B4-L	1.88E-09
B4-R	3.98E-10
B5-L	3.15E-10
B5-R	3.15E-10
B6-L	1.35E-06
B6-R	7.11E-08
BP-D3A	5.43E-08
BP-D3B	5.43E-08
BP-E5A	1.36E-08
BP-E5B	1.36E-08
BP-E6A	4.54E-09
BP-E6B	3.32E-07
C1-L	2.10E-09
C1-R	4.09E-10
C2-L	3.90E-10
C2-R	3.18E-10
C3-L	2.22E-07
C3-R	1.20E-08
C4-L	1.68E-07
C4-R	9.15E-09
C5-L	1.66E-08
C5-R	1.17E-09
C6-L	7.43E-07
C6-R	3.94E-08
D1-L	4.93E-12
D1-R	7.98E-10
D2-L	1.61E-09
D2-R	1.98E-09
D3-L	1.46E-09
D3-R	2.13E-09
D4-L	5.71E-08
D4-R	6.06E-08

Table 1.g – Release Frequencies for the Baseline SAMA Analysis

Release Mode	Frequency (/rx-yr)
E1-L	3.15E-10
E1-R	3.15E-10
E2-L	3.23E-10
E2-R	3.54E-10
E3-L	3.35E-10
E3-R	3.56E-09
E4-L	9.46E-09
E4-R	1.22E-08
E5-L	6.04E-10
E5-R	7.78E-10
E6-L	5.97E-08
E6-R	6.25E-08
NCF(A0)	2.60E-07
NCF(B0)1	1.17E-09
NCF(B0)2	1.48E-07
NCF(B0)3	1.72E-06
NCF(C0)1	2.41E-09
NCF(C0)2	2.95E-07
NCF(C0)3	1.35E-06
SUM	7.17E-06

Table 5.c – List of Equipment Failures and Human Actions with Greatest Potential for Reducing Risk at ANO-2 Based on Importance Analysis and Cut Set Screening

Event	Description	F-V	RAW	Top 100	SAMA
%RVR	Reactor vessel rupture <IE>	3.79E-02	140000.00	Y	
ISL	Mean annual frequency of ISLOCA	4.56E-02	140000.00	Y	CB-13 CB-14 CB-19 CB-20 CB-26
ZHF2C3-002	Failure to start standby SW pump and failure to align EFW/AFW suction to other CST on lo-lo level of 2T-41A(B) and failure to establish OT-cooling after total loss of FW.	6.80E-03	6700.00	Y	FW-19
DBD202D23F	DC Bus 2D23 Fault	5.94E-03	5450.00	Y	
ZHF2C2-008	Failure to align EFW/AFW suction to other CST on lo-lo level of 2T-41A(B) and failure to establish OT-cooling after total loss of FW	1.86E-03	1850.00	N	FW-19
SCC23DSCRN	SW pump discharge filter common cause failure	1.61E-01	1340.00	Y	CW-26 CW-27
SCC22P4ABC	SW pump common cause failure (3 of 3)	5.12E-02	1260.00	Y	CW-09
HCC2HRWTCV	CCF HPSI RWT suction flow path check valves (2 of 2) fail to open	4.99E-02	952.76	Y	CC-19
ACC2ESFAS1	Common cause failure of 2 or more ESFAS actuation relays to deenergize	3.60E-03	937.96	Y	CC-22
ACC2ESFAS2	Common cause failure of 2 or more ESFAS solid state relays to deenergize	3.60E-03	937.96	Y	CC-22
HCC23HPFTS	CCF of all 3 HPSI pumps to start	4.08E-02	897.25	Y	CC-02 CC-14
YCC2CTMSTR	Cont sump strainers plugged	7.42E-02	896.08	Y	CC-18
HCC23HPFTR	CCF of all 3 HPSI pumps to run	4.89E-03	893.84	Y	CC-02 CC-14
ACC2SIA13A	Common cause failure SIAS relays SSR-1A & 3A to respond	3.42E-03	892.92	Y	CC-22
ACC2SIA24A	Common cause failure SIAS relays SSR-2A & 4A to respond	3.42E-03	892.92	Y	CC-22
ACC2K104	Common cause failure of RAS relays K104A & K104B to deenergize	3.34E-03	872.44	Y	CC-22
ACC2RAS13A	Common cause failure RAS relays SSR-1A & 3A to respond	3.34E-03	872.44	Y	CC-22
ACC2RAS24A	Common cause failure RAS relays SSR-2A & 4A to respond	3.34E-03	872.44	Y	CC-22

Table 5.c – List of Equipment Failures and Human Actions with Greatest Potential for Reducing Risk at ANO-2 Based on Importance Analysis and Cut Set Screening					
Event	Description	F-V	RAW	Top 100	SAMA
%A	Large break LOCA <IE>	3.92E-02	576.48	Y	CC-01 CC-14 OT-07
HCC2HPINJF	Common cause failure of HPSI MOVs to open	4.05E-02	497.10	Y	CC-21
%M	Medium break LOCA <IE>	2.68E-02	405.87	Y	OT-02
ZHF2C2-014	Failure to establish flow to SG from AFW and failure to establish OT-cooling after total loss of FW	7.59E-03	292.55	N	FW-15
ECC23CCDGA	All 3 diesels (EDG1,2 and AAC) common cause failure to start	2.37E-03	131.92	N	AC/DC-02
ZHF2C2-045	Failure to override MSIS or CSAS and start AFW pump and failure to manually open EFW discharge valves (battery depletion)	1.09E-02	122.06	Y	AC/DC-06 FW-17
EMM2B6XXXX	480V LC 2B6 source module	9.69E-03	119.97	Y	
EMM2B5XXXX	480V LC 2B5 source module	8.11E-03	100.60	N	
ETM2A3XXXX	4160V SWGR 2A3 In test or maintenance	5.35E-03	95.46	Y	
ETM2B5XXXX	480V LC 2B5 In test or maintenance	5.28E-03	94.31	N	
%S	Small break LOCA <IE>	2.42E-01	82.89	Y	CC-02 CC-14 OT-02
ZHF2C2-007	Failure to align offsite power to bus 2A-1 or 2A-2 after auto-realign fail and failure to cross-tie 2B5/2B6	3.88E-03	78.54	N	AC/DC-09
ZHF2RCPTRP	Failure to trip reactor coolant pumps following loss of component cooling water	9.08E-02	76.53	Y	CW-24
YCC2CSTRNM	CCF cont sump MOVs (5649-1 and 5650-2)	3.19E-02	72.70	Y	CC-20
YCC2CSAXXA	CCF Of CS MOVs 2CV-5613-2 and 2CV-5612-1 fail to open	3.97E-02	72.14	Y	EV-30
ZHF2OTCLTP	Failure to establish once-through cooling after total loss of FW	3.59E-02	66.19	N	FW-15
ZHF2C2-052	Failure to override MSIS or CSAS and start AFW pump and failure to establish OT-cooling after total loss of FW	1.79E-02	65.04	N	AC/DC-06 FW-15
YCC2CCFMOV	Common cause failure of CS motor operated valves	2.81E-02	64.13	Y	EV-30

Table 5.c – List of Equipment Failures and Human Actions with Greatest Potential for Reducing Risk at ANO-2 Based on Importance Analysis and Cut Set Screening					
Event	**Description**	**F-V**	**RAW**	**Top 100**	**SAMA**
ZHF2QCSTXP	Failure to align EFW/AFW suction to 2T-41B on low-low level in 2T-41A	6.17E-03	62.66	Y	FW-19
PCC2MSIVFO	Common cause failure of MSIVs to close	1.13E-02	59.11	N	
RSP20P32AG	RCP-A seal leakage	4.75E-03	54.25	Y	CW-10 CW-11 CW-14
RSP20P32BG	RCP-B seal leakage	4.75E-03	54.25	Y	CW-10 CW-11 CW-14
RSP20P32CG	RCP-C seal leakage	4.75E-03	54.25	Y	CW-10 CW-11 CW-14
RSP20P32DG	RCP-D seal leakage	4.75E-03	54.25	Y	CW-10 CW-11 CW-14
SCC22NBSTR	A and C (2 of 3) SW strainers plugged	1.28E-03	48.12	N	
DMM202D11F	Battery 2D11 (Type-2) module	3.06E-03	44.43	Y	AC/DC-04 AC/DC-12
ETT2BOFT	Loss of offsite grid following trip	3.70E-03	43.57	N	AC/DC-21 AC/DC-22
DCD200133R	DC breaker 2D0133 transfers open	3.81E-03	42.73	Y	
DCD200142R	DC auto-transfer switch 142 transfers open	3.81E-03	42.73	Y	
ZHF2D31BCP	Failure to align DC bus 2D01 to alternate charger 2D31B	3.92E-03	40.16	N	AC/DC-10
ETM2B6XXXX	480V LC 2B6 in Test or Maintenance	2.21E-03	39.95	N	
ZHF2RCSD2P	Failure to cool down RCS to shutdown cooling conditions prior to RAS	3.67E-03	37.72	N	
QCC2EFMDPS	CCF to start of motor driven pumps 2P75 and 2P7B	6.27E-03	34.90	N	FW-15
ECC23CCDGF	All 3 diesels (EDG1,2 and AAC) common cause to run	1.89E-02	32.61	Y	AC/DC-02
%T14	Loss of AC bus 2B5 <IE>	2.90E-02	28.83	Y	AC/DC-09
ZHF2SGLCLP	Failure to locally open EFW discharge valve following battery depletion	1.02E-02	24.07	Y	FW-17
ZHF2C2-059	Failure to trip reactor coolant pumps following loss of CCW and failure to recover sump suction valves 2CV-5649-1 and 2CV-5650-2	1.41E-03	23.07	N	CC-20 CW-24

Table 5.c – List of Equipment Failures and Human Actions with Greatest Potential for Reducing Risk at ANO-2 Based on Importance Analysis and Cut Set Screening					
Event	**Description**	**F-V**	**RAW**	**Top 100**	**SAMA**
ZHF2C3-006	Failure to establish OT-cooling after total loss of FW and failure to align AAC DG on failure of EDG to start and failure to reduce loads and cross-tie 2A3/2A4	1.72E-03	22.76	N	FW-15 AC/DC-02 AC/DC-09
%T10	Loss of DC Bus 2D01 <IE>	6.66E-03	17.91	N	
RCSRV	1 of 2 SRVs fails to reclose after pressure relief	2.12E-01	15.05	Y	
ZHF2B5B6LP	Failure to cross-tie 480V vital buses 2B5 and 2B6 (battery depletion)	1.23E-03	13.25	N	AC/DC-09
%T7	Total loss of SW flow <IE>	2.10E-02	12.63	Y	CW-09
HCV2SI-7AN	Check valve 2SI-7A fails to open	5.70E-03	12.55	N	
%T11	Loss Of DC Bus 2D02 <IE>	3.96E-03	11.05	N	
%T5-B	Steam / feedwater line break on SG-B side inside MSIVs <IE>	5.35E-03	10.73	N	OT-06
%T5-A	Steam/feedwater line break on SG-A side inside MSIVs <IE>	5.35E-03	10.72	N	OT-06
HMV251031K	Motor-operated valve 2CV-5103-1 transfers closed	1.03E-03	9.03	N	
YMM2CSTRAK	Independent failures of cont sump train A	4.62E-03	8.41	N	
%T12	Loss of AC bus 2A3 <IE>	2.66E-03	7.75	N	AC/DC-09 AC/DC-13
YCV2BS-1AN	Check valve 2BS-1A fails to open	2.92E-03	6.92	N	
ECC215034F	Common cause failure of 2CV-1503-1 and 2CV-1504-2 to open	3.25E-03	6.84	N	
SMM2SE2P4C	SW segment 2P4C module	3.55E-03	5.73	N	CW-09
SMM22P4CXF	SW pump 2P4C module (passive faults)	3.13E-03	5.66	N	CW-09
CCV20S16AC	Check valve 2SI-16A fails to close	2.22E-03	5.50	N	
CCV20S16BC	Check valve 2SI-16B fails to close	2.22E-03	5.50	N	
CCV20S16CC	Check valve 2SI-16C fails to close	2.22E-03	5.50	N	
CCV20S16DC	Check valve 2SI-16D fails to close	2.22E-03	5.50	N	
HXV2SI-8BK	Manual valve 2SI-8B transfers closed	2.27E-03	5.01	N	
HCV22SI12N	Check valve 2SI-12 fails to open	1.87E-03	4.79	N	
HMM2PASMPB	Independent passive failures of HPSI pump train B	2.54E-03	4.79	N	

Table 5.c – List of Equipment Failures and Human Actions with Greatest Potential for Reducing Risk at ANO-2 Based on Importance Analysis and Cut Set Screening					
Event	Description	F-V	RAW	Top 100	SAMA
CCV20S15AN	Check valve 2SI-15A fails to open	1.83E-03	4.72	N	
CCV20S15BN	Check valve 2SI-15B fails to open	1.83E-03	4.72	N	
CCV20S15CN	Check valve 2SI-15C fails to open	1.83E-03	4.72	N	
CCV20S15DN	Check valve 2SI-15D fails to open	1.83E-03	4.72	N	
HCV2SI-7BN	Check valve 2SI-7B fails to open	1.83E-03	4.71	N	
HMM2ACTMPB	Independent active failures of HPSI pump train B	7.98E-03	4.65	N	
ZHF2HPSBSP	Failure to start standby HPSI pump after failure of auto pumps (SBLOCA)	2.53E-03	4.62	N	
HCV2SI13AN	Check valve 2SI-13A fails to open	1.66E-03	4.37	N	
HCV2SI13BN	Check valve 2SI-13B fails to open	1.66E-03	4.37	N	
HCV2SI13CN	Check valve 2SI-13C fails to open	1.66E-03	4.37	N	
HCV2SI13DN	Check valve 2SI-13D fails to open	1.66E-03	4.37	N	
QMM2TRANBA	EFW pump train B fails to deliver flow (type 1 faults)	7.98E-03	4.37	N	FW-15
QTM2EFWTBF	EFW pump train B unavailable due to maintenance	4.50E-03	4.36	N	FW-15
QXV2CV706R	Manual valve 2EFW-0706 transfers open	1.04E-03	4.34	N	
QMM2TRANBF	EFW pump train B fails to deliver flow (type 2 faults)	4.20E-03	4.27	N	FW-15
QXV2EFW06K	Manual Valve 2EFW-6 Transfers Closed	1.82E-03	4.23	N	
%T15	Loss of AC bus 2B6 <IE>	3.22E-03	4.09	N	AC/DC-09
QXV2EF10BK	Manual valve 2EFW-10B transfers closed	1.71E-03	4.02	N	
YCV2BS-1BN	Check valve 2BS-1B fails to open	1.42E-03	3.89	N	
%RB	SGTR on SG-B (SGTR-B) <IE>	1.01E-02	3.88	N	CB-01
%RA	SGTR on SG-A (SGTR-A) <IE>	1.01E-02	3.87	N	CB-01
ZHF2OTCLRP	Failure to establish once-through cooling after total loss of FW during SGTR	3.97E-03	3.83	N	FW-15
SXV2SW129K	Manual valve 2SW-129 transfers closed	1.42E-03	3.29	N	
SXV2SW131K	Manual valve 2SW-131 transfers closed	1.42E-03	3.29	N	
YMM2CSTRBK	Independent failures of cont sump train B	1.43E-03	3.29	N	

Table 5.c – List of Equipment Failures and Human Actions with Greatest Potential for Reducing Risk at ANO-2 Based on Importance Analysis and Cut Set Screening					
Event	**Description**	**F-V**	**RAW**	**Top 100**	**SAMA**
ECC2CCFDGF	2DG1/2 common cause failure to run	6.80E-03	3.27	Y	AC/DC-02
HCV2SI10BN	Check valve 2SI-10B fails to open	1.11E-03	3.25	N	
PRY201002T	S/G safety valve 2PSV-1002 fails to close (STM)	1.44E-02	2.93	N	CB-03
PRY201003T	S/G safety valve 2PSV-1003 fails to close (STM)	1.44E-02	2.93	N	CB-03
PRY201004T	S/G safety valve 2PSV-1004 fails to close (STM)	1.44E-02	2.93	N	CB-03
PRY201005T	S/G safety valve 2PSV-1005 fails to close (STM)	1.44E-02	2.93	N	CB-03
PRY201006T	S/G safety valve 2PSV-1006 fails to close (STM)	1.44E-02	2.93	N	CB-03
PRY201052T	S/G safety valve 2PSV-1052 fails to close (STM)	1.45E-02	2.93	N	CB-03
PRY201053T	S/G safety valve 2PSV-1053 fails to close (STM)	1.45E-02	2.93	N	CB-03
PRY201054T	S/G safety valve 2PSV-1054 fails to close (STM)	1.45E-02	2.93	N	CB-03
PRY201055T	S/G safety valve 2PSV-1055 fails to close (STM)	1.45E-02	2.93	N	CB-03
PRY201056T	S/G safety valve 2PSV-1056 fails to close (STM)	1.45E-02	2.93	N	CB-03
%T3	Loss of offsite power <IE>	5.94E-02	2.82	Y	AC/DC-02 AC/DC-09 AC/DC-13 AC/DC-21 AC/DC-22
SMM22P4AXA	SW pump 2P4A module (active faults)	4.52E-03	2.69	Y	CW-09
SMV215301C	MOV 2CV-1530-1 fails to close	1.53E-02	2.65	Y	CW-25
EMM2CB112X	4160V AC BKR 152-112 fault module	1.02E-03	2.53	N	
%T17	Closure of all MSIVs	6.25E-02	2.51	Y	
YMV256491N	Motor-operated valve 2CV-5649-1 fails to open	1.39E-02	2.49	Y	
SMM2SE2P4A	SW segment 2P4A module	1.11E-03	2.47	N	
ZBN3RUNF	LOOP recovery with >2 Run failures and no battery depletion	1.60E-02	2.38	Y	AC/DC-16
%T2	Loss of PCS <IE>	1.22E-01	2.28	Y	CW-01
%T18	Loss of condenser vacuum	1.08E-01	2.27	Y	
%T5-C	Steam line break outside MSIVs <IE>	2.95E-03	2.23	N	CB-03
YMV256502N	Motor-operated valve 2CV-5650-2 fails to open	1.13E-02	2.22	Y	
PMM2302FTC	Turbine bypass valve 2CV-0302 fails to reclose	2.56E-02	2.18	Y	

Table 5.c – List of Equipment Failures and Human Actions with Greatest Potential for Reducing Risk at ANO-2 Based on Importance Analysis and Cut Set Screening					
Event	**Description**	**F-V**	**RAW**	**Top 100**	**SAMA**
PMM2303FTC	Turbine bypass valve 2CV-0303 fails to reclose	2.56E-02	2.18	Y	
PMM2306FTC	Turbine bypass valve 2CV-0306 fails to reclose	2.56E-02	2.18	Y	
%T16	Spurious MSIS or CSAS signal <IE>	5.33E-03	2.16	Y	AC/DC-06
ZHF2AFWMSP	Failure to start AFW pump after an MSIS or CSAS	2.39E-03	2.14	N	FW-15
ZBN2RUNF	Loop recovery with 2 run failures and no battery depletion	2.17E-02	2.10	Y	AC/DC-16
QMM2CSTNKA	No flow from CST (type-1 faults)	1.77E-03	2.09	N	FW-19
YMM2CSAXXA	Independent failures of CS train a (type-1 failures)	1.10E-02	2.08	Y	
YMM2CSPMAA	Independent active faults of containment spray pump train A	3.82E-03	2.01	N	
DTM2002D11	125VDC battery 2D11 in test or maintenance	9.66E-04	31.46	Y	AC/DC-04 AC/DC-12
YMM2CSBXXA	Independent failures of CS train B (type 1 failures)	7.82E-03	1.77	Y	CC-20
STM2-2P4BM	2P4B in test & maintenance	2.85E-02	1.71	Y	CW-09
ETM2DGAACX	DG AAC in test or maintenance	9.71E-03	1.62	Y	AC/DC-02
QMM2STMADM	Steam admission valve 2CV-0340-2 or bypass valve 2CV-0205 fail	1.09E-02	1.57	Y	FW-15
QMM2TRANAA	EFW pump train A fails to deliver flow (type 1 faults)	1.05E-02	1.57	Y	FW-15
QTM2EFWTAF	EFW pump train A unavailable due to maintenance	3.83E-03	1.54	Y	FW-15
ZHF2CSSUMP	Failure to manually open containment sump suction valves 2CV-5649-1 and 2CV-5650	2.98E-02	1.51	Y	CC-20
ALT256361D	RAS level transmitter 2LT-5636-1 fails to respond	7.32E-03	1.51	Y	CC-23
ALT256372D	RAS level transmitter 2LT-5636-2 fails to respond	7.32E-03	1.51	Y	CC-23
ALT256393D	RAS level transmitter 2LT-5639-3 fails to respond	7.32E-03	1.51	Y	CC-23
ALT256404D	RAS level transmitter 2LT-5640-4 fails to respond	7.32E-03	1.51	Y	CC-23
EDG2DGAACF	Diesel generator AAC fails to run	3.90E-02	1.46	Y	AC/DC-02
QMM2TRANAF	EFW pump train a fails to deliver flow (type 2 faults)	1.03E-01	1.39	Y	FW-15
CXV2-5003K	2CV-5003 spuriously transfers closed since last test	3.72E-03	1.36	Y	CC-24

Table 5.c – List of Equipment Failures and Human Actions with Greatest Potential for Reducing Risk at ANO-2 Based on Importance Analysis and Cut Set Screening					
Event	**Description**	**F-V**	**RAW**	**Top 100**	**SAMA**
CXV2-5023K	2CV-5023 spuriously transfers closed since last test	3.72E-03	1.36	Y	CC-24
CXV2-5043K	2CV-5043 spuriously transfers closed since last test	3.72E-03	1.36	Y	CC-24
CXV2-5063K	2CV-5063 spuriously transfers closed since last test	3.72E-03	1.36	Y	CC-24
%T9	Loss of SW pump supplying loop II <IE>	5.36E-02	1.33	Y	CW-09
ZBN1RUNF	LOOP Recovery with 1 Run failure and no battery depletion	1.43E-02	1.26	Y	AC/DC-16
EDG2DG1XXF	2DG1 fails to run	1.89E-02	1.22	Y	AC/DC-02
EDG2DG2XXF	2DG2 fails to run	1.75E-02	1.21	Y	AC/DC-02
%T8	Loss of SW Pump Supplying Loop I <IE>	1.89E-02	1.12	Y	CW-09
%T1	Turbine Trip <IE>	1.45E-02	1.05	Y	
ZHF2HLINJX	Failure to initiate hot leg injection	3.91E-03	1.04	Y	
%T6	Reactor trip initiating event <IE>	6.35E-02	1.01	Y	
THF2RCPTRP	Failure to trip RCPs after loss of CCW	9.87E-02	1.00	Y	CW-10 CW-11 CW-14 CW-24
THF2OTCLTP	Failure to establish once-thru cooling after total loss of FW (transient case)	7.54E-02	1.00	Y	FW-15
YHF2CSSUMP	Failure to recover sump suction valves 2CV-5649-1 AND 2CV-5650-2	5.14E-02	1.00	Y	CC-20
DBT2DSCD11	Battery 2D11 discharged	3.79E-02	1.00	Y	AC/DC-04 AC/DC-05 AC/DC-10 AC/DC-12
QHF2SGLCXP	Failure to manually open EFW discharge valves to S/G A or S/G B	3.42E-02	1.00	Y	FW-17
DHF2D31BAP	Operator fails to transfer 2D31B to alternate power source	3.37E-02	1.00	Y	AC/DC-10 AC/DC-24
SHF2SWCCWP	Failure to restore SW to CCW	3.25E-02	1.00	Y	CW-06 CW-21 CW-23
QHF22P75SP	Failure to establish flow to SGs from AFW	2.25E-02	1.00	Y	FW-15
THF2RCSTRX	RCPs are tripped after loss of CCW (compliment to THF2RCSTRP)	1.89E-02	1.00	Y	CW-10 CW-11 CW-14 CW-24

Table 5.c – List of Equipment Failures and Human Actions with Greatest Potential for Reducing Risk at ANO-2 Based on Importance Analysis and Cut Set Screening					
Event	**Description**	**F-V**	**RAW**	**Top 100**	**SAMA**
QHF2A1CSTP	Failure to align Q-CST (T-41B) to EFW suction	1.87E-02	1.00	Y	FW-19
QHF2QCSTXP	Failure to align EFW/AFW suction to other CST on lo-lo level of 2T-41A(B)	1.78E-02	1.00	Y	FW-19
SHF2SWISOP	Failure to isolate ACW or CCW before SW equipment fails.	1.58E-02	1.00	Y	CW-21 CW-23 CW-25
DBT2DSCD12	Battery 2D12 discharged	1.49E-02	1.00	Y	AC/DC-04 AC/DC-05 AC/DC-10 AC/DC-12
IVKI	Collapsed PDS marker	1.48E-02	1.00	Y	EV-15 EV-16 EV-17 EV-31
DHF2D32BAP	Operator fails to transfer 2D32B to alternate power source	1.16E-02	1.00	Y	AC/DC-10 AC/DC-24
SHF2SWRECP	Failure to start standby SW pump	9.83E-03	1.00	Y	CW-21 CW-23
FHF2MFWTRP	Failure to restart tripped MFW pump	4.26E-03	1.00	Y	FW-15
DHF2D32BCP	Failure to align DC bus 2D02 to alternate charger 2D32B	2.73E-03	1.00	Y	AC/DC-10

Table 5.d – Attainable Benefit of Eliminating Failures without SAMAs		
Event Name	**Description**	**Benefit**
RCSRV	1 of 2 SRVs fails to reclose after pressure relief	$117,400
%T18	Loss of condenser vacuum	$58,200
%T6	Reactor Trip Initiating Event <IE>	$36,000
%T17	Closure of all MSIVs	$33,300
PMM2302FTC	Turbine bypass valve 2CV-0302 fails to reclose	$18,700
PMM2303FTC	Turbine bypass valve 2CV-0303 fails to reclose	$18,700
PMM2306FTC	Turbine bypass valve 2CV-0306 fails to reclose	$18,700
%RVR	Reactor vessel rupture <IE>	$18,000
%T1	Turbine Trip <IE>	$8,500
YMM2CSAXXA	Independent failures of CS train A (type-1 failures)	$8,300
YMV256491N	Motor-operated valve 2CV-5649-1 fails to open	$8,200
PCC2MSIVFO	Common cause failure of MSIVs to close	$8,100
EMM2B6XXXX	480V LC 2B6 source module	$7,500
EMM2B5XXXX	480V LC 2B5 source module	$6,800
DBD202D23F	DC bus 2D23 fault	$6,500
YMV256502N	Motor-operated valve 2CV-5650-2 fails to open	$6,200
ETM2B5XXXX	480V LC 2B5 in test or maintenance	$5,000
HMM2ACTMPB	Independent active failures of HPSI pump train B	$4,200
ETM2A3XXXX	4160V SWGR 2A3 in test or maintenance	$4,100
%T10	Loss of DC bus 2D01 <IE>	$3,900
ETM2B6XXXX	480V LC 2B6 in test or maintenance	$3,300
YMM2CSPMAA	Independent active faults of containment spray pump train A	$2,900
HCV2SI-7AN	Check valve 2SI-7A fails to open	$2,800
%T11	Loss of DC bus 2D02 <IE>	$2,700
ZHF2HLINJX	Failure to initiate hot leg injection	$2,400
YMM2CSTRAK	Independent failures of cont sump train A	$2,100
ECC215034F	Common cause failure of 2CV-1503-1 and 2CV-1504-2 to open	$2,100
DCD200133R	DC breaker 2D0133 transfers open	$2,000
DCD200142R	DC auto-transfer switch 142 transfers open	$2,000
ZHF2RCSD2P	Failure to cool down RCS to shutdown cooling conditions prior to RAS	$1,700
YCV2BS-1AN	Check valve 2BS-1A fails to open	$1,500
HMM2PASMPB	Independent passive failures of HPSI pump train B	$1,300
EMM2CB112X	4160v AC BRK 152-112 fault module	$1,300
CCV20S16AC	Check valve 2SI-16A fails to close	$1,100
CCV20S16BC	Check valve 2SI-16B fails to close	$1,100
CCV20S16CC	Check valve 2SI-16C fails to close	$1,100
CCV20S16DC	Check valve 2SI-16D fails to close	$1,100
HXV2SI-8BK	Manual valve 2SI-8B transfers closed	$1,100
ZHF2HPSBSP	Failure to start standby HPSI pump after failure of auto pumps (SBLOCA)	$1,100
HCV22SI12N	Check valve 2SI-12 fails to open	$1,000

Table 5.d – Attainable Benefit of Eliminating Failures without SAMAs		
Event Name	**Description**	**Benefit**
QXV2EFW06K	Manual valve 2EFW-6 transfers closed	$1,000
QXV2EF10BK	Manual valve 2EFW-10B transfers closed	$1,000
SMM2SE2P4A	SW segment 2P4A module	$1,000
SCC22NBSTR	A and C (2 of 3) SW strainers plugged	$900
CCV20S15AN	Check valve 2SI-15A fails to open	$900
CCV20S15BN	Check valve 2SI-15B fails to open	$900
CCV20S15CN	Check valve 2SI-15C fails to open	$900
CCV20S15DN	Check valve 2SI-15D fails to open	$900
HCV2SI-7BN	Check valve 2SI-7B fails to open	$800
HCV2SI13AN	Check valve 2SI-13A fails to open	$800
HCV2SI13BN	Check valve 2SI-13B fails to open	$800
HCV2SI13CN	Check valve 2SI-13C fails to open	$800
HCV2SI13DN	Check valve 2SI-13D fails to open	$800
YCV2BS-1BN	Check valve 2BS-1B fails to open	$700
SXV2SW129K	Manual valve 2SW -129 transfers closed	$700
SXV2SW131K	Manual valve 2SW -131 transfers closed	$700
YMM2CSTRBK	Independent failures of cont sump train B	$700
HMV251031K	Motor-operated valve 2CV5103-1 transfers closed	$500
QXV2CV706R	Manual valve 2EFW-0706 transfers open	$500
HCV2SI10BN	Check valve 2SI-10B fails to open	$500