April 29, 2002

NOTE TO: Cynthia Carpenter, Chief
Inspection Program Branch
Division of Inspection Program Management
Office of Nuclear Reactor Regulation

Patrick D. O'Reilly
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Office of Nuclear Regulatory Research

FROM: Mark F. Reinhart, Chief**/Signed by M. Caruso for**
Licensing Section
Probabilistic Safety Assessment Branch
Division of Systems Safety and Analysis
Office of Nuclear Reactor Regulation

SUBJECT: RESULTS OF THE GRAND GULF NUCLEAR STATION SDP PHASE 2 NOTEBOOK BENCHMARKING VISIT

During February, 2002, NRC staff and a contractor visited the Grand Gulf Nuclear Station (GGNS) site to compare the GGNS Significance Determination Process (SDP) Phase 2 notebook and licensee's risk model results to ensure that the SDP notebook was generally conservative. GGNS's PSA did not include external initiating events; and therefore, no sensitivity studies were performed to assess the impact of these initiators on SDP color determinations. In addition, the results from analyses using the NRC's draft Revision 3i Standard Plant Analysis Risk (SPAR) model for GGNS were also compared with the licensee's risk model. The results of the SPAR model benchmarking effort will be documented in a separate a trip report to be prepared by the Office of Nuclear Regulatory Research.

In the review of the GGNS SDP notebook, it was found that some changes to the SDP worksheets were needed to reflect how the plant is currently designed and operated. Forty-five hypothetical inspection findings were processed through the SDP notebook. Results from this effort indicated that the total risk impacts modeled in the SDP notebook were underestimated by 29 percent, overestimated by 31 percent, and adequately estimated by 40 percent. The reviewers found that if nine fixes, including two specific changes to the Loss of Offsite Power (LOOP) worksheets, were made to the SDP notebook, the results would be 16 percent underestimation, 24 percent overestimation, and 60 percent adequate estimation of risk impacts.

Attachment A describes the process and results of the comparison of the GGNS SDP Phase 2 Notebook and the licensee's PSA.

If you have any questions regarding this effort, please contact See-Meng Wong.

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301-415-1125

Attachments: As stated

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G://SPSB/wong/GG-Ltr-report.wpd ML021220661 nrr-096

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SUMMARY REPORT ON BENCHMARKING TRIP TO Grand Gulf Nuclear Station (Feb. 4 - 7, 2002)

J. C. Higgins
Brookhaven National Laboratory
February 22, 2002

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1 Introduction

This report compares the NRC Risk Informed Inspection Notebook, developed by Brookhaven National Laboratory (BNL) staff, and the licensee risk model for the Grand Gulf Nuclear Station (GGNS) to ensure that the Notebook is generally conservative. The benchmarking is being performed after the worksheets have been revised to include the appropriate licensee comments and recommendations, and the special initiator worksheets have been completed.

Rev. 0 of the Grand Gulf Nuclear Station Inspection Notebook (also called the SDP notebook) was originally prepared in August, 2001. The GGNS SDP Notebook was reviewed prior to this benchmarking visit in order to identify potential changes that may be needed. A few changes were made (see below) and some areas were identified for clarification during the onsite review (see below). Some other areas were identified for changes that will be made subsequent to the site visit during the Maintenance Phase.

Main changes to Notebook prior to onsite visit

- Added RPT plus other minor edits on Table 2
- Changed safety function names to standard used for BWRs; e.g., CHR, HPCS, RCIC, LPI throughout the worksheets (w/s)
- Added ETs for TPCS, LDC1, & LDC2
- Used the simpler "train" terminology for CHR under mitigating systems
- On ATWS w/s, changed OVERPR to multi-train system
- For LDC1 deleted LDEP and the first sequence on the w/s.

Questions for Site PRA Staff

1. What is the total PRA IE frequency for those transients that involve a loss of PCS?
2. Verify date of new PRA information.
3. Verify base case CDF of 5.54E-6 events per reactor-year and a truncation value.
4. Check note 3 after Table 2 versus notes within Table 2 on pumping saturated water.
5. Is there an IA dependency of Fire Water, as shown in Table 2?
6. On Trans, etc. for PCS and LDEP do you need both condensate and condensate booster pumps?
7. Discuss use of CRD for injection: HEP for use, early versus late, 1 vs. 2 pumps, do you need any operation of RCIC, etc. before crediting CRD.
8. Verify the 3.5 minutes for DEP in the note for Trans and other w/s.
9. Check all HEPs for new PSA.
10. What is the equivalent size break to a SORV? Discuss IORV and SORV? Is w/s good for both?
11. Explain the lack of a need for CHR on successful LPI (see trans ET seq. 7).
12. MLOCA - why is ET sequence 9 a success with no CHR? similar question on sequence 6 & 8 for LLOCA. Depending on answer, re-evaluate ET structure to move CHR to right.
13. LOOP - Is REC 10 hours or 8 hours correct. We have 8 in w/s, but p. 54 of PRA document says 10 hrs.

14. Verify that the CRD pumps are powered by normal AC and are not available during a LOOP unless offsite power is recovered.
15. Do we need a LOOP with failure of one EDG (LEAC) worksheet?
16. Have we given too much credit to cross tie of EDG-3 on LOOP (2+1=3).
17. LOOP - why is CHR not questioned on ET sequences 7, 12, & 15? Do we need to transfer to TPCS?
18. In the w/s sequences with REC 1 and REC 8 should we subsume them together to REC 8?
19. Is 19/20 SRVs correct for OVERPR on ATWS?
20. Need information on operator action for HPCS/level control on ATWS for note.
21. On ATWS, can you use condensate pumps for an MSIV induced ATWS?
22. Is ATWS the only place you credit CV? Should we break out CV on separate line from CHR?
23. Do we need the LAC w/s?
24. Why do you credit PCS on loss of DC for RB but not for GG?
25. Why do you lose LPCS on LDC2?
26. On LPSW should we have 1/3 LPCI & 1/2 CHR?
27. Does LDC1 cause a loss of EDG1?

The licensee provided answers to all the above questions during the site visit.

Proposed Changes to Notebook for subsequent to site visit:

1. Update Table 2 to latest format.
2. Correct the note 1 contained on the special initiator
3. Update the Table of Contents
4. Update the w/s to correspond to the new ETs.
5. Correct spacing on w/s sequences.
6. Drop CHR from LDC1 w/s.
7. Add Table 2 note re: what is cooled by CCW and discussion of cooling by ECCS pump room HVAC.
8. CHR: Credit both SPC and containment spray for all worksheets.

2 Summary Results from Benchmarking

The onsite visit was conducted by an NRC headquarters PSA representative with support from a BNL contractor. The Region IV Senior Reactor Analyst (SRA) was scheduled to participate but was sent to evaluate an incident at another site. During the February 4 to 7 visit, we met with Grand Gulf, River Bend (RBS), and licensee corporate PSA representatives at the Grand Gulf plant site and conducted the benchmarking of both the GGNS and RBS SDP notebooks.

The initial activities included reviewing with the licensee, the updates made to the GGNS notebook as described in Section 1 above, and providing an updated copy of the SDP Notebook to the GGNS licensee. We then provided the GGNS license with the questions in Section 1, and a general set of BWR-6 questions. The GGNS licensee researched the related information and provided answers to the team. The licensee provided updated information to the review team based on the 1996 GGNS PSA Update, Rev.1, based on plant information

through June, 1995. This PSA has an internal events CDF of 5.46 E-6 events per reactor year, which includes about 1% contribution due to internal flooding. The GGNS licensee also gave the review team a few added comments to the SDP Notebook, which were valuable and improved the notebook contents. These comments were incorporated into the SDP notebook before beginning the benchmarking activities. Notable changes made, based on the licensee's comments and justifications, were:

- Dropped credit for early inventory injection by CRD.
- Changed credit for cross-tie of SSW to operator action 2 (except on MLOCA, LLOCA, & ATWS)
- Changed credit for PCS to operator action 3.
- Changed LOOP REC8 to REC 10 and adjusted operator action credits. Dropped credit for CRD.
- Dropped credit for condensate pumps and CV in ATWS
- Added LPCS credit on LDC2
- Corrected equipment on LPSW

The licensee provided additional PRA information in response to team questions throughout the visit. Information included: definition of basic events, cutsets, RAW values, system design information, analysis assumptions and results, and event trees.

The team computed the thresholds in RAW values for the different SDP colors based upon a current PRA total internal events CDF of 2.25 E-5 events/reactor-year. The team had pre-selected a fairly large list of components and human actions, as listed in Table 1 below, that would be evaluated for the effect of having the component or human action fail. Prior to the site visit, the review team developed the color corresponding to failure of each item. This set of items was modified slightly during the onsite review. We then used the latest revised version of the SDP notebook to develop the color corresponding to failure of each item, and compared that to the color that would be implied by the item's RAW value from the PRA.

In developing the colors from the notebooks, the review team evaluated all sequences in each worksheet that contained the item (component or human action). A number was obtained for each re-evaluated sequence. We then used a "counting rule" to cascade lower value sequences to higher value ones as follows. For example three sequences of value 8 (shorthand for an estimated sequence frequency of 1 E-8 events/reactor-year) were equivalent to one sequence of value 7. Likewise 3 sequences of value 7 (3-7s) were equivalent 1 sequence of value 6(1-6). Also, 3-6s were equal to 1-5, and so on. Colors were developed as follows:

Sequences of value 7, 8, and higher	Green
Sequences of value 6	White
Sequences of value 5	Yellow
Sequences of value 4 or less	Red

When the above described counting rule was needed to obtain a color rather than a direct correlation from a sequence, then in Table 1 we note that it was obtained "by the counting rule" or "bcr."

Discussion of Non-conservative Benchmark Results

At the completion of the benchmarking runs, the review team noted some differences between the risk importance of components determined by the licensee's RAW values and by the notebooks, wherein the SDP notebook provided non-conservative results. As a result, some additional changes were made in order to bring the GGNS SDP notebook into closer agreement with the GGNS PSA. These changes are discussed below.

The TPSW Event Tree and worksheet were modified to add a SSW event that would capture the effects of common cause failure (CCF) of the SSW system that was modeled in the current GGNS PSA and that contributed notably to the CDF results. There is also a contribution of SSW CCF to other initiators, but this was added to the notebook as a comment.

Non-conservative results related to five items on the Loss of Offsite Power (LOOP) worksheet were identified during the benchmarking. We also noted that the GGNS PSA cutsets have a higher frequency (by over 10 times) than the similar sequences in the LOOP worksheet. This has been a common problem for BWR 5s and 6s. This is typically caused by a few items:

- LOOP initiating frequency is typically 3 to 5 E-2 events per reactor-year (3.9E-2 for GG) but we have LOOP in Row 2 of Table 1.
- RCIC failure probability (fp) is sometimes greater than 0.1 (for GGNS, some failure modes have a fp ~0.5), but we credit it with 1 in the worksheets.
- Non-recovery probabilities are often in the upper end of the decade range for establishing credit.
- The worksheets do not account for common cause (CC) failure between EDGs 1 & 2 and EDG 3 (the HPCS EDG). For plants that account for this aspect, their CC fp is around 5 E-4. Yet, we give a credit of 3 for EDGs 1 & 2 and 2 more for EDG3/HPCS, for a total of 5. The GGNS PSA does not currently account for this CC failure mode, but is planning on adding it in their next PSA update this summer.
- There are some LOOP sequences in the licensee's PSA but are not captured in the SDP notebook event tree (ET) and worksheet.

In order to address this problem for GGNS, we examined several "fixes" to the LOOP worksheet.

- Move LOOP to row 1 of Table 1. This corrected two of the five non-conservatisms.
- The GGNS PSA has a LOOP core damage scenario that we did not capture, with success of EDG 1 & 2, but failure of EDG-3, REC1, RCIC, and DEP. We explored adding this sequence but it addressed only one of the non-conservatisms, and that was able to be addressed by other "fixes."
- In those sequences that involve failure of all 3 EDGs, reduce the base case credit from 5 to 4.
- Change the credit for REC1 from 1 to 0.
- Change the evaluation rules for inspection findings on an EDG (such that on a finding on any EDG, the credit for the other EDGs is only 1 each).
- We also tried various combinations of these fixes, since no one by itself was sufficient.

The final selection of changes were to:

- Change the credit for REC1 from 1 to 0.
- In those sequences that involve failure of all 3 EDGs, reduce the base case credit from 5 to 4 to account for CC failure of all 3 EDGs.

The fix (of REC1 receiving ‘0' credit) effectively assumes that all LOOP events will last at least one hour and occurs at a probability of (3.9 E-2 * 0.22) 9 E-2, which is much closer to a row 2 assignment in Table 1. A finding on REC1 is then evaluated as part of the LOOP initiating event. These two fixes remove 3 of the 5 non-conservatisms, leaving only REC10 and EDG2 non-conservative by one order of magnitude. If we had selected the fix for CC failure of 3 EDGs and had moved LOOP up to row 1, that would have removed all non-conservatisms except for EDG 2.

After the first BWR-6 visit to Perry, it was recommended that, a benchmarking trip should be performed at another BWR-5/6 in order to consolidate the insights and enable the production of improved SDP notebooks for all BWR-5 and 6 plants. The BNL contractor notes that this was the 4th BWR-5/6 plant that has had a benchmarking visit, and several useful insights on GGNS plant systems and PRA logic model were obtained from the licensee.

Table 1: Comparison of Sensitivity Calculations
Between Phase 2 Worksheets and GGNS RAW Values
(CDF = 5.46 E-6; RAW splits - 1.18, 2.83, 19.32)
Truncation level 1 E-10

Item Out of Service	SDP Work-sheet Color	GGNS Basic Event	GGNS RAW ratio	Color by GGNS RAW	Mod. SDP Worksheet Color	Comments
Component						
HPCS	R_{bcr}	System	10.5	Y	R_{bcr}	conservative
ECCS pump rm HVAC item	-	HPCS room cooler	7.1	Y	R_{bcr}	conservative
SSW-C train C	-		11.9	Y	R_{bcr}	conservative
EDG-3	W_{bcr}	System	4.0	Y	Y	
RCIC	W_{bcr}	System	2.2	W	Y_{bcr}	conservative[6]
PCS	G	FW controller N19-HW-CTR004-G	1.6	W	W	
1 SRV fto	W_{bcr}	ATWS overpressure M increased	1.0	G	W_{bcr}	conservative
2 SRVs fto	Y	M failed	8.7	Y	Y	
1 SRV ftc	G	P1	1.003	G	G	
LPCS	G	System	1.0	G	G	
RHR- pump A	Y_{bcr}	pump A ftr	1.5	W	W_{bcr}	
RHR-pump B	W_{bcr}	pump B ftr	1.08	G	W_{bcr}	conservative

Item Out of Service	SDP Work-sheet Color	GGNS Basic Event	GGNS RAW ratio	Color by GGNS RAW	Mod. SDP Worksheet Color	Comments
RHR-pump C	G	pump C ftr	1.0	G	G	
RHR HX A	Y_{bcr}	HX plug E12-PG-HX-B001AL	1.59	W	W_{bcr}	
RHR HX B	W_{bcr}	HX plug E12-PG-HX-B002AL	1.58	W	W_{bcr}	
1 CV valve	G	not credited in PSA	-	-	-	dropped from w/s
1 DD Fire Pump	G	P64-FR-DPC003AG	1.07	G	G	
SPMU 1 train	G	1 train	1.04	G	G	
SPMU-cc	Y	both trains	3.85	Y	Y	
One SLC pump	G	1 train	1.0	G	G	
Both SLC pumps	Y	System	1.38	W	Y	conservative
RPT 1 train	G	not modeled at train level in PSA	-	-	G	
RPT both trains	Y	System	35.1	R	Y	non-conservative[8]
EDG 1	G	1 train	2.0	W	W	
EDG 2	G	1 train	3.1	Y	W	non-conservative[6]
4160 AC Div. 1	Y_{bcr}	R21-LP-AC-15AA-A	2.0	W	Y_{bcr}	conservative
4160 AC Div. 2	Y	R21-LP-AC-16AB-B	123	R	R_{bcr}	
1 CRD pump	G	C11-FR-MP-C001BG	6.8	Y	G	non-conservative[7]

Item Out of Service	SDP Work-sheet Color	GGNS Basic Event	GGNS RAW ratio	Color by GGNS RAW	Mod. SDP Worksheet Color	Comments
2 CRD pumps	W	System	7.0	Y	G	non-conservative[7]
IA item	W_{bcr}	supply valve to Aux. Bldg. PVF026A-T	3.1	Y	Y	
SSW pump A	Y_{bcr}	pump A	1.88	W	W_{bcr}	
SSW pump B	Y_{bcr}	pump B	3.08	Y	Y_{bcr}	
PSW item	G	System	1.03	G	G	
TBCW item	G	System	7.2	Y	W	non-conservative[7]
CCW item	G	System	1.0	G	G	
DC-Div 1	R_{bcr}	System	5.9	Y	R_{bcr}	conservative
DC-Div 2	R_{bcr}	System	2.0	W	Y_{bcr}	conservative
DC Battery 1	R_{bcr}		2.84	Y	Y	
DC Battery 2	R_{bcr}		2.1	W	W_{bcr}	
DC Charger 1	R_{bcr}	not in cutsets	-	-	-	
DC Charger 2	R_{bcr}	not in cutsets	-	-	-	
EC	W	not modeled in PSA	-	-	W	
Operator Actions						
DEP	R_{bcr}		400.	R	R	

Item Out of Service	SDP Work-sheet Color	GGNS Basic Event	GGNS RAW ratio	Color by GGNS RAW	Mod. SDP Worksheet Color	Comments
LDEP	W	not modeled as such in PSA	-	-	-	
SLC	Y		2.1	W	Y	conservative
INH	Y		12.4	Y	Y	
CV	G	not credited in PSA	-	-	-	
REC1	G		2.0	W	W	
REC10	G		7.4	Y	W	non-conservative[6]
ATWS: HPCS & level control	G		1.07	G	G	
FPW injection	G		5.7	Y	W	non-conservative[9]
DGX	G		1.03	G	G	
SW cross-tie	G	see note 10	-	-	W_{bcr}	

Table 1 Notes:

1. GGNS RAW values for internal events, average maintenance case.
2. The delta CDF used in RAW value calculations represented the change in CDF due to the component being out of service for 1 year.
3. The subscript bcr means “by counting rule.”
4. For a component such as a pump, we examined the RAW values for the basic events both for “failure to start” and “failure to run,” and either selected the highest (more conservative) value here, or used a synthesized RAW value separated

calculated by the licensee that included all failure modes. Where the basic event column indicates "System," the licensee calculated a system RAW by setting all the appropriate system events to true (or failed) and resolving the model to obtain the new higher CDF.

5. For those items where the basic event column is blank, the licensee used a synthesized RAW value, separately calculated, that included several failure modes.
6. LOOP items: Five LOOP items were found to be non-conservative during the benchmarking (EDG 1, 2, & 3, REC1, and REC10). To address this, we decreased the credit for REC1 from 1 to 0, and when EDG3 and EAC1&2 appear in the same sequence of the LOOP worksheet, the credit was reduced from 5 to 4, in order to account for common cause failure of all three EDGs. This left two non-conservatisms, namely EDG-2 and REC10. It also pushed RCIC from a match to a conservative result. See also discussion of non-conservative results in Section 2 above.
7. CRD items: The PSA credits both late and early injection with CRD (LICRD & EICRD). The high importance of CRD and its support system (TBCW) is due to the credit for EICRD. EICRD requires about one hour of injection with either RCIC or FW prior to its use. It also requires 2/2 pumps, CRD support systems (IA, CCW, TBCW, & PSW), and operator action to maximize flow. Thus, as with other BWR notebooks, we did not credit EICRD. The licensee stated that in Rev. 2 of the PSA they will no longer credit EICRD.
8. RPT: The notebook and the PSA have the same sequence for RPT that assigns CD in the event of an ATWS with total failure of RPT. However, the PSA has an initiating event frequency (IEF) of 1.2 E-4 for ATWS, while the notebook uses 1 E-5. This one order of magnitude is the reason for the one color difference. The licensee stated that they believe the notebook's value is more correct than the PSA. In the planned Rev. 2 update to the PSA, the licensee is planning to reduce their IEF to 1 E-5 or perhaps lower. The notebook will then agree with the PSA.
9. Fire Protection Water (FPW): The licensee models a common cause (CC) failure of Standby Service Water (SSW) in several sequences (notably TRANS, LOOP, TIA, and TPSW). This is modeled at the fault tree level. With this CC failure, most ECCS injection is lost. Only RCIC and LPCS remain, but they both fail subsequently from temperature (RCIC in about 6 hours due to SP heat-up, and LPCS in 12-14 hours due to loss of room cooling). Once all of these injection sources are lost the only remaining creditable source is FPW, hence its high RAW value in the PSA. The notebook did not originally contain the SSW CC failure. We have added it as a top event to the TPSW event tree and workbook, which raised our importance of FPW and SSW somewhat. We have also added notes to the other three affected ETs regarding SSW CC. In Rev. 2 of the PSA, the licensee is planning to reduce the credit for FPW in these sequences by modeling a proceduralized SSW recovery action, that they currently do not credit.
10. The PSA models several injection actions (including the SW cross-tie) as the same basic event, therefore one cannot separately calculate the RAW for the SW cross-tie. The licensee is planning to change this in Rev. 2 of the PSA.

Table 2: Comparative Summary of the Benchmarking Results

	SDP Worksheet		SDP Worksheet Modified	
	Number of Cases	**Percentage**	**Number of Cases**	**Percentage**
SDP: Non-Conservative	13	29	7	16
SDP: Conservative	14	31	11	24
SDP: Matched	18	40	27	60
Total	45	100	45	100

Both the conservative and the non-conservative items noted above can be grouped into a somewhat smaller set of items. The seven non-conservative items fall into four groups: LOOP-related (REC10, EDG 2), CRD related (one and two CRD pumps, and TBCW), RPT, and Fire Protection Water. Each of these areas is discussed in the notes to Table 1.

Prior to the onsite adjustments in the notebook, there were 13 conservative items. Of these, two were conservative by two orders of magnitude. After the adjustments, there are 11 conservative items, which fall into seven groups: 1 SRV fails to open, RHR pump B, SLC, 4160 VAC Div. 1, HPCS related, DC buses, and RCIC. None of these items are more than one order of magnitude conservative.

3 Additional Proposed Modifications to SDP Worksheets

3.1 Specific Changes to the Rev-0 SDP Worksheet for GGNS

A number of changes were made to the GGNS worksheets. Changes made before the onsite visit are noted in Section 1 above. A number of additional changes, made during and after the plant onsite visit, are summarized in Section 2 above and are contained in the updated notebook.

3.2 Generic Changes in IMC 0609 for Guidance to NRC Inspectors

None.

3.3 Generic Change to the SDP Notebooks

None.

4 Discussion on External Events

As analyzed by the licensee's updated PRA models, the core damage frequency estimates for internal initiators was 5.46 E-6 events/reactor-year. The GGNS PSA does not have an integrated external event PRA. The licensee noted that their IPEEE study for fire events has a CDF of 8.8 E-6 events per reactor year. The IPEEE seismic analysis used the non-quantitative seismic margins method. Other external events were also qualitative per the NRC SRP.

The licensee's fire IPEEE together with the supporting information (not in the IPEEE report) may provide enough information to estimate risk importance using an SDP methodology. The IPEEE used cable routing information for App. R SSD systems and selected other important IPE front line systems together with a fire area analysis to develop lists of failed equipment due to a fire. Other systems were conservatively assumed to be failed, since the precise cable routing information was not developed. Depending on damaged equipment, a LOOP might be assumed. This was then related to the fire initiating frequency and used in a PRA/IPE type analysis to develop accident sequences and CDF.

Thus, there may be sufficient information to provide insights to potential changes in color evaluation based on consideration of fire events, but not other external events.

5 References

1996 Grand Gulf Nuclear Station PSA Update, Rev. 1, with plant information through June, 1995.

ATTACHMENT 1

List of Participants

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Loys Bedell	**(Entergy)**