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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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 RIVER BEND 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 River Bend Station (RBS) Significance Determination Process (SDP) Phase 2 notebook and licensee's risk model results to ensure that the SDP notebook was generally conservative. RBS'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 RBS 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 RBS 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-nine hypothetical inspection findings were processed through the Rev. 0 SDP notebook, and fifty-five hypothetical cases were processed after changes were made to the worksheets. Results from this effort indicated that the total risk impacts modeled in the SDP notebook were underestimated by 28 percent, overestimated by 33 percent, and adequately estimated by 39 percent. The reviewers found that if thirteen fixes, including two specific changes to the Loss of Offsite Power (LOOP) worksheets, were made to the SDP notebook, the results would be 9 percent underestimation, 27 percent overestimation, and 64 percent adequate estimation of risk impacts.

Attachment A describes the process and results of the comparison of the RBS 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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SUMMARY REPORT ON BENCHMARKING TRIP FOR River Bend Station (RBS) (Feb. 4 - 7, 2002)

J. C. Higgins
Brookhaven National Laboratory
February 27, 2002

Attachment A

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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 River Bend Station (RBS) 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. That revision was completed in early 2001.

Rev. 0 of the River Bend Station Inspection Notebook (also called the 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 RBS specific questions 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 as part of the Rev. 1 update to the inspection notebook.

Main Changes to Notebook prior to onsite visit

- Split the credit for RHR and SPCC in CHR. Changed credit for CHR from operator action to multi-train system.
- Added event trees for TPCS, TCCP, TDCI & TDCII.
- Changed the safety function SPC to CHR on MLOCA and LLOCA
- Changed safety function LPI1 to LPI, and LPI2 to LI on MLOCA and LLOCA
- On the LOOP worksheet, dropped credit for CRD in sequences 1 and 2 of worksheet since normal power is not available unless offsite power is recovered.

Questions for Site PRA Staff

1. Need to update IE frequencies consistent with latest version of PSA.
2. Verify date of new PSA information.
3. Verify base case CDF of 9.44E-6 events per reactor-year and a truncation value of 1E-9.
4. Do you need condensate pumps to run FW pumps?
5. 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.
6. Is auto ADS inhibited even on a Trans event?
7. Check all HEPs used in new PSA.
8. Discuss use of SPCC for CHR and injection, HEPs and credit. Should we add credit for containment fans to CHR?
9. Preferred abbreviation for River Bend, RBS?
10. Switch LPI and EICRD on ET?
11. For ET sequence #3 on SLOCA, is this still a success with containment failure at 14 hours on a loss of CHR?
12. What is the equivalent size break to a SORV?
13. MLOCA - why is ET sequence 6 a success with no CHR? Similar question on sequence 5 for LLOCA. Depending on answer, re-evaluate ET structure to move CHR to right.

14. LOOP - Is REC 18 hours still valid with containment failure at 14 hours on a loss of CHR?
15. Verify that the CRD pumps are powered by normal AC and are not available during a LOOP unless offsite power is recovered.
16. Probably should not credit SPCC on LOOP for LPI and CHR since the pumps do not receive emergency power (would not be available on ET seq. 1). This change would be significant since the base case for the first two w/s sequences would drop from 7 to 6.
17. Should we add CHR to LOOP worksheet and ET?
18. ATWS - Why is HPCS an operator action here? Verify operator action credit of 2 for SW cross-tie.
19. TCCP - Is this preferred or LCCP?
20. How many SRVs are fed from each bus? Add information to TDCI & TDCII.
21. Effect on RPCCW and CRD as a result of TDC? Update note 2.
22. Obtain valve information for ISLOCA table.
23. What is the support equipment needed for the SBO DG?
24. Is the HEP for CHR on MLOCA in the E-2 range? Do we want CHR credit of 2 on MLOCA, LLOCA, and ATWS?
25. Are SPMU dump valves needed on LOCAs?
26. Do we need a LOOP with failure of one EDG (LEAC) worksheet?
27. Check on need for LOIA worksheet.

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

Additionally, the BNL contractor prepared a list of major assumptions sometimes used in BWR6 designs that need to be verified at the site. This list was provided to the licensee, who also provided answers to those questions.

<u>Proposed Changes to Notebook for subsequent to site visit:</u>

Add additional clarifying notes to Table 2.

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 River Bend, Grand Gulf, 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 RBS notebook as described in Section 1 above, and provided an updated copy of the SDP Notebook to the RBS licensee. We then provided the RBS licensee with the questions in Section 1. The RBS licensee researched the related information and provided answers to the team. The RBS 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:

- Adjustment of the initiating event (IE) frequencies to those currently used in the RBS PSA and revision of Table 1 to agree with the new IE frequencies.
- Moved LNSW from row 3 to row 2.
- A few minor changes to Table 2.
- Added a Loss of Instrument Air (LOIA) event tree (ET) and worksheet.
- Dropped credit for EICRD.
- Dropped credit for condensate pumps in LDEP due to double counting problem.
- Changed the credit for CHR from 2 to 3 in the MLOCA and LLOCA worksheets.
- In LOOP, changed REC18 to REC12. Revised credit for all recovery of offsite power items based on non-recovery probabilities in latest version of PSA. Also dropped credit for SPCC on LOOP.
- In the ATWS worksheet: added inhibit of HPCS and ADS; added level control with HPCS, changed credit for SLC from 1 to 3, changed credit for SW cross-tie from 2 to 1, changed CHR from operator action to multi-train system.
- Revised the SORV worksheet to address both IORV and SORV. Also dropped credit for PCS here to match generic rules of SDP notebook development.

The licensee provided updated information to the team for the benchmarking based on the RBS PSA, Rev. 3, dated Jan. 11, 2001. This was supplemented by additional PSA information provided in response to team questions throughout the visit. Information included: definition of basic events, detailed 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 PSA total internal events CDF of 9.44 E-6 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 list 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 PSA.

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 to 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 and Additional Changes to Notebook

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 RBS notebook into closer agreement with the RBS PSA and with generic development rules relative to the risk-informed notebooks. These are discussed below.

One SRV failing to close (ftc) was non-conservative. Credit had been given for PCS in the SORV worksheet, but the SDP notebook development rules typically no longer allow such credit here. This worksheet is meant to address both an IORV and an SORV that transfers from other initiating events. We do note that the RBS PSA models an IORV as an initiator and an SORV (P1) transfers to the SLOCA event tree. We will continue to address both of these in the IORV/SORV worksheet, but we have dropped credit for PCS there. This corrected the non-conservatism for 1 SRV ftc.

Five items from the LOOP worksheet were non-conservative: REC4, REC6, REC12, SBODG, and FPW. We also noted that the RBS PSA cutsets have a higher frequency (by about10 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 (3.5 E-2 for RBS) but we have LOOP in Row 2 of Table 1.
- RCIC failure probability (fp) is sometimes greater than 0.1.
- 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

typically 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 RBS PSA currently accounts for this CC failure mode with a fp of 5.4 E-4.

- There are some LOOP sequences that are 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 RBS, we examined several "fixes" to the LOOP worksheet: a change to the DEP credit as discussed below, a change to the CC failure probability for EDGs, moving the LOOP initiating event frequency (IEF) up to row 1 of Table 1, and changing the method of evaluating an EDG finding. As a result we made two changes:

(1) In the updated PSA, the licensee has modeled common cause failure of all three EDGs (1, 2, & 3) with a failure probability of 5.4 E-4. Therefore, when EDG3 and EAC1&2 appear in the same sequence of this worksheet, the credit has been reduced from 5 to 4, in order to account for common cause failure of all three EDGs.

(2) The updated PRA estimates a HEP value for DEP of 1.7E-4. However, in an SBO scenario, the SRVs will run out of air to operate them at about 10 to 14 hours, unless a special diesel driven air compressor (C4) is operated to provide backup air to the SRV accumulators. Since the failure probability of operators to utilize this compressor is 3 E-2, we have given a credit of 2 to DEP for the LOOP worksheet. We did not move LOOP up to row 1 since the IEF for LOOP is still less than 5 E-2 events per reactor year. The result is that we move the evaluation of the five noted items closer to a match, but we were still non-conservative but one order of magnitude for all five items. (If one were to also move LOOP to row 1, we would clear 4 of the 5 non-conservatisms.) The non-conservatism of FPW is also affected by some of the other worksheets and the CC service water failure, as discussed below.

NSW, RPCCW, and SWC were all 2 orders of magnitude non-conservative before the benchmarking was completed. The PSA has several SSW CC failure events (involving SSW MOVs) modeled that each have a fp of 2.6 E-4. This would imply a failure probability on the order of 1 E-3. As a result, both the TCCP and the TNSW Event Tree and worksheet were modified to add an SSW common cause event that would capture the effects of common cause failure of the SSW and NSW systems that were modeled by RBS and that contributed notably to the CDF results.   We added SSW to the ETs and worksheets for TNSW and TCCP as a multi-train system with a credit of 3, and such that the CC failure of SSW leads to core damage. The RBS PSA models an operator recovery action at 0.1, which we credited for TNSW. These changes eliminated the non-conservatisms for these three items.

Table 2 provides a summary of the benchmarking results. The team's initial quantification of the RBS Notebook had 14 (28%) non-conservative items and 16 (33%) items that were more conservative than the colors that were based on the RAW values from the licensee's PSA. The team's final quantification of the RBS Notebook had 5 (9%) non-conservative items and 15 (27%) items that were more conservative than the colors that were based on the RAW values from the licensee's PSA. (See Table 2.)

After the first BWR-6 visit to the Perry station, 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 3rd BWR-5/6 plant that has had a benchmarking visit and several useful insights on RBS plant systems and PRA logic model were obtained from the licensee.

Table 1: Comparison of Sensitivity Calculations Between Phase 2 Worksheets and RBS RAW Values
(CDF = 9.44 E-6; RAW splits - 1.11, 2.06, 11.59)
Truncation level 1 E-9

Item Out of Service	SDP Work-sheet Color	RBS Basic Event	RBS RAW ratio	Color by RBS RAW	Mod. SDP Worksheet Color	Comments
Component						
HPCS	W	CSH-CSHMNTHPCS	2.6	Y	Y	
EDG-3	W	EPS-DGNMNTEG001C	1.8	W	W	
RCIC	W	ICS-MDLMNTSYSTEM	1.6	W	Ybcr	conservative
PCS	Y	PCS-MDPCC3FWS-PMP	1.12	W	W	
1 or 2 SRVs fto	G	ADS-SRVFTOSRV41A ADS-SRVFTOSRV41B	1.0	G	Wbcr	conservative
1 SRV ftc	G	P1	1.6	W	W	
LPCS	G	CSL-MDPMNTPC001	1.10	G	G	
RHR- pump A	Y	RHS-MDPFTRC002A, FTS2A	1.3	W	Ybcr	conservative
RHR-pump B	Y	RHS-MDPFTRC002B, FTS2B	1.14	W	Ybcr	conservative
RHR-pump C	G	RHS-MDPFTRC002C, FTS2C	1.01	G	G	

Item Out of Service	SDP Work-sheet Color	RBS Basic Event	RBS RAW ratio	Color by RBS RAW	Mod. SDP Worksheet Color	Comments
RHR HX A or B	Y	RHS-HEXPLGEB001A	1.3	W	Ybcr	conservative
RHR injection valve	-		1.6	W	Ybcr	conservative
1 CV valve	G	None - note 8	1.0	G	G	
1 Fire Pump	G	FPW-DDPFTSP1A	1.06	G	G	
SPCC 1 train	G	-	~ 1.0	G	G	
SPCC-cc	W	SPC-HEXPLGSPC	1.01	G	G	
One SLC pump	W	SLS-MDPMNT-C001A	1.0	G	G	
Both SLC pumps	Y	SLS-MDPMNT-C001A, C001B	1.04	G	Y	conservative[9]
RPT 1 train	G	-	~1.0	G	G	
RPT both trains	Y		1.02	G	Y	conservative[9]
EDG 1	W	EPS-DGNMNTEG001A	9.3	Y	Ybcr	
EDG 2	W	EPS-DGNMNTEG001B	6.9	Y	Ybcr	
4160 AC Div. 1	Y	EPS-BUSLOFIENS1A	19.2	R	R_{bcr}	
4160 AC Div. 2	R_{bcr}	EPS-BUSLOFIENS1B	13.8	R	R_{bcr}	
1 CRD pump	G	RDS-MDPFTRC001A	1.01	G	G	
2 CRD pumps	W	RDS-MDPFTRC001A, 1B	1.01	G	G	

Item Out of Service	SDP Work-sheet Color	RBS Basic Event	RBS RAW ratio	Color by RBS RAW	Mod. SDP Worksheet Color	Comments
PAS, IAS or SAS item	R_{bcr}	INI-TIASI	1.35	W	Y_{bcr}	conservative - This assumes that PCS and SPCC are lost.
SSW pump A	Y	SWP-MDPFTSSWP2A	1.66	W	Y_{bcr}	conservative
SSW train B	Y	SWP-MOVFTOVF055B	7.8	Y	Y_{bcr}	
NSW item	G	SWP-MDPFTRNSWP7C	7.4	Y	Y	note 10
SWC item	G	SWP-MDPFTRSWCP1C	7.3	Y	Y	note 10
RPCCW item	G	CCP-MDPFTSCCPP1C, CCPTRAINC	5.0	Y	Y	note 10
ECCS HVAC items	-	HVR-FANFTSUC5 (HPCS)	2.6	Y	Y	
ECCS HVAC items	-	HVR-FANFTSUC6 (RCIC/LPCS/RHRA)	4.2	Y	R_{bcr}	conservative
ECCS HVAC items	-	HVR-FANFTSUC9 (RHR B/RHRC)	1.2	W	Y	conservative
DC-Div 1	R	EPS-BUSLOFIENB1A	20.0	R	R_{bcr}	
DC-Div 2	R	EPS-BUSLOFIENB1B	24.0	R	R_{bcr}	

Item Out of Service	SDP Work-sheet Color	RBS Basic Event	RBS RAW ratio	Color by RBS RAW	Mod. SDP Worksheet Color	Comments
DC Battery 1	R	EPS-BATLOPIENB1A	9.7	Y	Y	
DC Battery 2	R	EPS-BATLOPIENB1B	7.0	Y	Y_{bcr}	
DC Charger 1	R	EPS-CHGLOPIENB1A	39.7	R	R_{bcr}	
DC Charger 2	R	EPS-CHGLOPIENB1B	35	R	R_{bcr}	
CFS item	-	CFS-FANFTSSUC1A	1.3	W	W_{bcr}	
Operator Actions						
DEP	Y	ADS-HEEHFRINDIY	263	R	R	
SLC	Y	BC-SLC	1.04	G	Y	conservative[9]
INH	Y	NOADS	1.02	G	Y	conservative[9]
CV	G	-	~1.0	G	G	
REC1	G	ORA-OSPIHRS	1.08	G	G	
REC4	G	ORA-OSP4HRS	1.34	W	G	non-conservative note 11
REC6	G	ORA-OSP5HRS	1.64	W	G	non-conservative note 11
REC12	Y	ORA-OSP12HRS	15.0	R	Y	non-conservative note 11
LICRD	G	BC-CRDSTART	1.0	G	G	

Item Out of Service	SDP Work-sheet Color	RBS Basic Event	RBS RAW ratio	Color by RBS RAW	Mod. SDP Worksheet Color	Comments
FPW injection	W	BC-FPWSTART	2.54	Y	W	non-conservative note 11
LDEP	W	not modeled as such in PSA	-	-	W	
SBO DG	G	BC-DCDGN	1.5	W	G	non-conservative note 11
RHR SP cooling		BC-RHRAB	9.17	Y	R	conservative
SW cross-tie	W	BA-SSWINJ, BC-SSWINJ	1.01	G	G	

Table 1 Notes:

1. For this table we have selected the River Bend RAW values based on the internal events PSA, average maintenance case model.
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 requested the RAW values that were the highest (more conservative) value for the basic events. For example, consider both "failure to start" and "failure to run," and either select the highest or use a separately calculated synthesized RAW value that includes all failure modes.
5. For those items where the basic event column is blank either we were unable to identify a PSA modeled basic event that was equivalent or the licensee used a synthesized RAW value separated calculated that included all failure modes.

6. For PCS, if we assume a total loss, then the color was Y before benchmarking and W after. If we just assume a degradation and reduce credit from 3 to 2, then we get a G. Further the licensee provided the team with a best estimate RAW value for PCS, but noted that they do not model PCS per se. Rather, as with most other sites, they have a much more detailed model. Also they take considerable credit for recovery of PCS components, which increases the overall importance of PCS.
7. We were not able to obtain RAW values for one train of SPCC or one train of RPT due to modeling in the PSA.
8. CV is not credited in the level 1 PSA due to its small size (3 inches).
9. ATWS: RBS uses an initiating event frequency of about 1 E-7 events per reactor year for ATWS (when including the mechanical failure of control rods), whereas the notebook has placed ATWS generically in row 5 (1 E-5). This leads to conservative results for some ATWS related components by two orders of magnitude.
10. SSW and NSW common cause failure issue. NSW, the related SWC , and RPCCW were all two orders of magnitude non-conservative. This was fixed by adding SSW CC failure to the ET and worksheet for TNSW and TCCP, as per the PSA. This eliminated these 3 non-conservatisms.
11. Five items from the LOOP worksheet were non-conservative: REC4, REC6, REC12, SBODG, and FPW. We made two changes to the worksheet, but were still left with these five non-conservative items. See discussion in section 2 above.
12. RHR train B is noticeably more important than just RHR pump B, since the RHR B injection valve is required for RHR SPC, LPCI, SW cross-tie and FPW injection.

Table 2: Comparative Summary of the Benchmarking Results

	SDP Worksheet		SDP Worksheet Modified	
	Number of Cases	**Percentage**	**Number of Cases**	**Percentage**
SDP: Non-Conservative	14	28	5	9
SDP: Conservative	16	33	15	27
SDP: Matched	19	39	35	64
Total	49	100	55	100

Notes:

1. The five non-conservative items were all related to the LOOP worksheet and are: REC4, REC6, REC12, SBODG, and FPW.

2. Some of the 15 conservative items can grouped as follows: 5 RHR related (RHR SPC, RHR/LPCI injection valve, RHR HX, RHR pump B, RHR pump A); 4 ATWS related (SLC operator action, INH, 2 trains of RPT, 2 SLC pumps); and 2 HVAC related (ECCS HVAC UC 6, & ECCS HVAC UC 9). The other four conservative items are: 1 or 2 SRVs fail to open, SSW pump A, an IA item, and RCIC.

3 Additional Proposed Modifications to SDP Worksheets

3.1 Specific Changes to the Rev 0 SDP Worksheets for RBS

A number of changes were made to the RBS worksheet. Ones made before the onsite visit are noted is 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 Notebook

None.

4 Discussion on External Events

As analyzed by the licensee's updated PSA models, the core damage frequency estimates for internal initiators was 9.44 E-6 events/reactor-year. River Bend does not have an integrated external event PSA. The licensee noted that their IPEEE study for fire, floods, and seismic events was not quantified and does not have sufficient information to provide insights to potential changes in color evaluation based on consideration of external events.

5 References

River Bend PSA, dated Jan. 11, 2001 based on plant information through November, 2000.

ATTACHMENT 1

List of Participants

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Jim Higgins	**(BNL)**
John Schroeder	**(INEEL)**
Tom Hunt	**(RBS)**
Loys Bedell	**(Entergy)**