Exelon Root Cause

ROOT CAUSE REPORT

#3 **TITLE:** Inadequate response to unplanned environmental tritium releases from Braidwood Station due to weak managerial oversight and the lack of integrated procedural guidance.

Unit(s): Braidwood Units 1 and 2

Event Date: 11/30/2005
Event Time: 11:50

Action Tracking Item Number: 428868

Report Date: 02/14/06

Sponsoring Manager: Janice Kuczynski

Investigators:	**Position**
Jason Eggart	Braidwood Chemistry Lead Investigator
Tom Leffler	Root Cause (RC) Qualified Investigator
Randy Kalb	Dresden Chemistry Investigator
Kim Aleshire	Braidwood EP (ODCM) Investigator
Glen Vickers	LaSalle RP Investigator
Scott Kirkland	Quad Cities Investigator
Jim Crawford	BWD CMO RC Qualified Investigator
Mike Miller	Braidwood Operations
Jeff Burkett	Braidwood Operations
Dan Stroh	Braidwood Engineering
Carl Dunn	Senior Mentor

Executive Summary:

Reason for Investigation:

Braidwood Station identified low levels of elevated tritium in the groundwater on and in the vicinity of Braidwood Station property (See Attachment 7 for Map). The presence of these elevated levels exceeds levels specified in Illinois EPA regulations (Attachment 10). The Illinois Environmental Protection Agency (IEPA) groundwater limit for tritium concentration parallels the Federal EPA regulation for annual radiation limits due to drinking water radioactivity. The statutes imply that four (4) mrem would not be exceeded if less than two liters of water at the IEPA limit were ingested daily for a year. In addition, the U.S. Nuclear Regulatory Commission (NRC) provides limits on liquid effluent releases and how those effluents must be

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monitored and reported. The NRC has reached a preliminary conclusion that Braidwood may not have satisfied all associated regulations in this regard. When the inspection exit for the current NRC review is completed, any potential violations will be entered into the Braidwood Corrective Action Process. This report provides insights on the causes of these potential violations and associated corrective actions. Additional investigation will be performed commensurate with the content of any such potential violations.

Scope of the Review:

The first focus of this root cause investigation is to determine the root cause(s) of and appropriate corrective actions for the unplanned tritium releases from Braidwood Station (See Attachment 1). The Braidwood Tritium Remediation Team has responsibility under Action Request (AR) 435383 for corrective actions to prevent future unplanned tritium releases to the environment and to remediate the existing condition of detectable tritium in groundwater on and in the vicinity of Braidwood Station property. The second focus of this root cause team is to evaluate the effectiveness of Braidwood's response to the Circulating Water (CW) Blowdown (B/D) leaks, which deposited tritiated water on the ground during 1998 and 2000 as well as during the smaller volume leaks, which both preceded and succeeded the 1998 and 2000 leaks. If this investigation determines that Braidwood's response actions were not effective, this root cause team will determine the root cause(s) and appropriate corrective actions for those ineffective response actions.

Root Causes and Corrective Actions to Prevent Recurrence (CAPRs):

The root cause of the large volume leaks in 1998 and 2000 is documented in Root Cause Report (RCR) 38237, which determined that the Circulating Water (CW) Blowdown (B/D) Vacuum Breaker (VB) Valves had inadequate preventative maintenance programs and inadequate design configuration (**Root Cause 1).** The Corrective Actions to Prevent Recurrence (CAPRs) from RCR 38237 were to institute a Preventative Maintenance Program and system modifications, which are complete and have been verified to be effective in preventing major vacuum breaker valve failures that resulted in large volume spills (**CAPR 1**). The root cause of the small tritiated water leaks, which both preceded and succeeded the 1998 and 2000 leaks, was that the need for a near zero leakage standard was not identified due to a then-existing lack of Technical Rigor/Questioning Attitude (**Root Cause 2**). The Braidwood Tritium Remediation Team will determine the methodology and implement the plan for future radiological releases, including leakage standards under IR 435383 and effectiveness review ATI# 428868 (**CAPR 2**). HU-AA-102 and HU-AA-1212, Technical Human Performance Practices and Technical Task Risk/Rigor Assessment, Pre-Job Brief, Independent Third Party Review, and Post-Job Brief procedures have been instituted to improve technical rigor, questioning attitude, and attention to detail (**CAPR 3**).

This Root Cause Team determined that Braidwood's response to the 1998 and 2000 events was ineffective. The response to the 1998 and 2000 releases of radioactivity (tritium) to an unplanned location is indicative of ineffective corrective actions. As directed by the root cause charter (Attachment 1), these ineffective corrective actions are addressed in this root cause report.

The first root cause for the ineffective response was a lack of integrated procedural guidance to ensure proper recognition, evaluation, and timely mitigation of the radiological spill events (**Root Cause 3**). Integrated procedures will be developed and implemented to provide detailed spill and leak response requirements which will ensure full compliance with

State and Federal laws and regulations and to integrate Exelon resources to respond to radiological leaks and spills (**CAPR 4**). A second root cause for the ineffective response was weak management review and oversight of spill response activities (**Root Cause 4**).

Specifically, management had a weak questioning attitude and an inadequate challenge culture regarding the 17 CW B/D leaks over the 10 year period bridging 1996 to 2006. Exelon Corporate, the Issues Management Team, and Braidwood Senior Management did not track characterization and mitigation plans to completion during and following the year 2000 spill. HU-AA-102 and HU-AA-1212, Technical Human Performance Practices and Technical Task Risk/Rigor Assessment, Pre-Job Brief, Independent Third Party Review, and Post-Job Brief procedures have been instituted to improve technical rigor, questioning attitude, and attention to detail (**CAPR 3**).

OP-AA-106-101-1002, Exelon Nuclear Issues Management, will be revised to: 1) improve Corrective Action Program (CAP) controls of Issues Management teams, 2) utilize the tools and techniques of the Exelon HU-AA-102 and HU-AA-1212, Technical Human Performance Practices and Technical Task Risk/Rigor Assessment, Pre-Job Brief, Independent Third Party Review, and Post-Job Brief procedures, 3) strengthen reporting requirements to station Senior Management, and 4) define station Senior Management responsibilities for oversight and challenge of events and issues from initial identification to final disposition (**CAPR 5**).

Extent of Condition:

Exelon Nuclear is evaluating the potential for unplanned tritium releases at each of its facilities, with added emphasis on Pressurized Water Reactors due to tritium production rates. Nuclear Event Report (NER 428868-12) will require all Exelon Sites to take actions to research historical spills and determine if tritium remediation is required. The nuclear industry will be informed of the issue through a Nuclear Network Operating Experience Report (NNOE 428868-13). Other spill type (Hazardous Material) response procedures were reviewed and determined to have effective guidance through the Hazmat and Environmental programs (Attachments 2 & 8). These programs and procedures will receive further review and update to integrate radiological interfaces (CAPR 3).

Risk Assessment/ Reportability:

The Nuclear Safety Risk Assessment showed no impact on station operation or response to postulated accident conditions. The event was reportable under Reportability Manual, SAF 1.9, News Release or Notification of Other Government Agencies per 10 CFR 50.73.

Previous Events:

Since 1996, 17 CW B/D valve leaks were noted in the Braidwood Corrective Action Database and Work Control System as documented in Table 1 of this report in the Events Description Section. Responses varied from a request for a normally scheduled repair to immediate remediation efforts. The best response, which occurred in year 2000, removed water from the spill area, but did not effectively determine the extent of condition for full remediation.

Condition Statement:

In response to an Illinois Environmental Protection Agency (IEPA) inquiry in March 2005, Braidwood Station began taking a series of groundwater samples within Braidwood Station property boundaries. Some of those samples identified elevated levels of tritium in the Braidwood Station groundwater. Issue Report (IR) # 328451 documented these monitoring results in April 2005. This sampling continued over a period of eight months.

In response to the results of these initial and follow-up monitoring samples, an Issues Management Team was formed on November 30, 2005 in accordance with Exelon procedure OP-AA-106-101-1002. Additional sampling resulted in elevated tritium levels being identified in groundwater in the vicinity of Circulating Water (CW) Blowdown (B/D) system Vacuum Breakers (VB) #2 and CW B/D VB #3, which had experienced large volume leaks in 1998 [(VB 3) Problem Identification Form (PIF) # A1998-04324] and in 2000 [(VB 2) IR # 38237].

On 30 November 2005, the Issues Management Team (IMT) initiated IR# 428868 reporting that elevated levels of tritium had been detected in onsite groundwater sampling wells and triggering this root cause investigation and report. Subsequent sampling identified elevated tritium levels outside Braidwood Station property boundaries.

On 16 December 2005, the Illinois Environmental Protection Agency (IEPA) issued Violation Notice W-2005-00537 to Exelon Generation – Braidwood Station, alleging Impairment of Resource Groundwater.

See Attachment 6 for an overview of the Circulating Water (CW) Blowdown (B/D) System operation. See Attachment 7 for a map of the affected areas.

Event Description:

Braidwood Station identified elevated levels of tritium in the groundwater that exceed Illinois EPA regulations (Attachment 10). Due to the extended period of time and the number of events covered in this root cause investigation, the timeline became very complex. For clarity, the Event Description has been organized as follows:

The Events and Causal Factors (E&CF) Chart has been placed in Attachment 4. Page 1 of 3 of the E & CF chart depicts the timeline for all vacuum breaker issues. Page 2 of 3 and page 3 of 3 depict barrier analysis of the events on VB-2 and VB-3. Displayed in this event description section are:

a. Table 1, Circulating Water (CW) Blowdown (B/D) Leak Table, which details the leaks that have been identified during this investigation.

b. Event timeline summary with events that led up to this Root Cause Investigation.
   1. Attachment 12, CW B/D VB-2 and VB-3 detailed timelines.

a. <u>Leaks that are within the scope of this investigation</u>

The elevated levels of tritium have been determined to have originated from historical spills from the CW B/D system. Since 1996, 17 CW B/D vacuum breaker leaks were noted in the Braidwood Corrective Action Database and work control database. The following table is a summary of leaks identified from records, including the station's response.

This team did not locate any computerized records of the Work Orders or Problem Identification Forms (PIFs) prior to approximately 1996. As such, the quantification of and response to these events had to be recreated from historical documents and interviews of involved personnel. Two means of identifying the impact of potential leaks from initial plant operation in 1988 to 1996 were considered. The first was to pull microfiche records for review and the second was to perform direct characterization of the conditions in the vicinity of all of the Circulating Water (CW) Blowdown (B/D) Vacuum Breakers (VBs).

Because of the need to have full confidence in the characterization of conditions in the vicinity of the vacuum breakers, the decision was made to install both deep and shallow monitoring wells in the vicinity of all of the CW B/D vacuum breakers. This was determined to be preferable to depending on locating microfiche records for possible leaks and monitoring only those locations.

Table 1: CW B/D Leak Table

#	Date	Event	Leak Size	RESPONSE						
				WR	PIF/ CR/IR	Immediate Action	Particulate Sample	Tritium Sample	10 CFR 50.75(g)	Resolution
1	11/27/96	VB-1 leak	~250,000 gals	WO 96111970	Process had personnel decide WR or PIF. So, no PIF, WR only.	Requested repair.	No 1996 documents found. Will be addressed under ATI# 435383	No 1996 documents found. Tritium plume was identified in 2006. Will be addressed under ATI# 435383	No 1996 documents found. Will be addressed under ATI# 435383	06/19/97 1" pipe to air release valve broke. Tritium plume was identified around VB-1 in 2006. Remediation being addressed under IR# 435383.
2	1/5/98	VB-2 leak	Small leak.	WR# 98000682	Process had personnel decide WR or PIF. So, no PIF, WR only.	Requested repair	No 1998 documents found. Will be addressed under ATI# 435383	No 1998 documents found. Tritium plume was identified in 2005. Will be addressed under ATI# 435383	No 1998 documents found. Will be addressed under ATI# 435383	11/08/00 replaced the float, replaced vacuum breaker and isolation valve. Tritium plume was identified around VB-2 in 2005. Remediation being addressed under IR# 435383.
3	12/4/98	VB-3 leak - seat	Caused flooding. ~ 3M gals	WO 98127749	A1998-04324	Isolated air release valve until parts could be received. This stopped this leakage.	04/26/01 Soil Particulate radioactivity above background.	No 1998 documents found. Tritium plume was identified in 2005. Will be addressed under ATI# 435383	07/25/01 evaluation detected particulate radioactivity.	05/20/02 1" pipe to the air release valve broke due to corrosion. Guide post sheared weld off float. Entire vacuum breaker replaced (July 2001). Tritium plume was identified around VB-3 in 2005. Remediation being addressed under IR# 435383.
4	11/6/00	VB-2 leak-seat	Caused flooding. ~ 3M gals	WO 98003276	A2000-04281 Root Cause 38237	Replaced vacuum breaker	Particulate radioactivity above background.	Tritium plume was identified around VB-2 in 2005. Will be addressed under ATI# 435383	Yes. Sampling detected particulate radioactivity.	11/06/00 Float broke on vacuum breaker. Tritium plume was identified around VB-2 in 2005. Remediation being addressed under IR# 435383.
5	11/10/00	VB-6 leak – seat	Small leak	WO 99231846	None. IR should have been written.	Requested repair.	No 2000 documents found. Will be addressed under ATI# 435383	No 2000 documents found. 2006 samples show no tritium in the groundwater	No 2000 documents found. Will be addressed under ATI# 435383	10/17/05 Valve assembly replaced. 2006 remediation sampling showed no tritium in the groundwater at this location.

#	Date	Event	Leak Size	RESPONSE						
				WR	PIF/ CR/IR	Immediate Action	Particulate Sample	Tritium Sample	10 CFR 50.75(g)	Resolution
6	11/20/00	VB-1 leak	Vacuum breaker lifting.	WO 99233404	None. IR should have been written.	Rebuilt valve.	11/20/00 samples reported negative for detectable radioactivity.	Tritium sampling was performed no detectable activity.	Yes. Sampling reported negative for detectable radioactivity	11/21/00 Rebuilt valve internals. Tritium plume was identified around VB-1 in 2006. Remediation being addressed under IR# 435383.
7	6/18/01	VB-3 leak	½ GPH leak from main vacuum breaker.	WO 98127749	A2001-01806	Sampled water.	No 2001 documents found. Will be addressed under ATI# 435383	Tritium plume was identified around VB-3 in 2005. Will be addressed under ATI# 435383.	No 2001 documents found. Will be addressed under ATI# 435383	05/20/02 Rebuilt valve. Tritium plume was identified around VB-3 in 2005. Remediation being addressed under IR# 435383.
8	6/18/01	VB-9	Water in vault.	N/A	A2001-01806	Sampled water.	Negative for detectable particulate radioactivity.	No 2001 documents found. No tritium in groundwater at this location reported in 2006.	No 2001 documents found. 2006 remediation sampling showed no tritium.	No active leak. Attributed to groundwater. 2006 remediation sampling showed no tritium in the groundwater at this location.
9	6/18/01	VB-10	Water in vault	N/A	A2001-01806	Sampled water.	Negative for detectable particulate radioactivity.	No 2001 documents found. No tritium in groundwater at this location in 2006.	No 2001 documents found. Will be addressed under ATI# 435383	No active leak. Attributed to groundwater. 2006 remediation sampling showed no tritium in the groundwater at this location.
10	6/18/01	VB-11	Water in vault	N/A	A2001-01806	Sampled water.	No 2001 documents found. Will be addressed under ATI# 435383	No 2001 documents found. No tritium in groundwater in 2006.	No 2001 documents found. Will be addressed under ATI# 435383	No active leak. Attributed to groundwater. 2006 remediation sampling showed no tritium in the groundwater at this location.
11	5/4/02	VB-3 leak - vent	Seepage	WO 00440231	106767	Requested repair.	Sample showed above background particulate activity. Will be addressed under ATI# 435383	Per IR, RP was sampling. No documents found. Will be addressed under ATI# 435383	No 2002 documents found. Will be addressed under ATI# 435383	05/20/02 replaced air release valve. Tritium plume was identified around VB-3 in 2005. Remediation being addressed under IR# 435383.

#	Date	Event	Leak Size	RESPONSE						
				WR	PIF/ CR/IR	Immediate Action	Particulate Sample	Tritium Sample	10 CFR 50.75(g)	Resolution
12	8/20/03	VB-4 seat	1 gpm to vault, no flooding	WO 99243232	172376	None	Sample analysis detected no particulate radioactivity	No 2003 documents found. Tritium plume was identified in 2006. Will be addressed under ATI# 435383	No 2003 documents found. Will be addressed under ATI# 43538310.	9-9-03 replaced seat ring/float and top gasket.
	8/27/03				173204	Stopped *mod* testing.				Tritium plume was identified around VB-4 in 2006. Remediation being addressed under IR# 435383.
13	9/11/03	VB-4 seat	20-40 drops/min	WO 99243232	175241	Secured booster pumps.	No 2003 documents found. Will be addressed under ATI# 435383	No 2003 documents found. Tritium plume was identified in 2006. Will be addressed under ATI# 435383	No 2003 documents found. Will be addressed under ATI# 435383	10/22/03 No work performed. Leak determined to be from operating the system at low flow. Tritium plume was identified around VB-4 in 2006. Remediation being addressed under IR# 435383.
14	11/18/04	VB-8	Popping / leaking, small leak within pit	WO 00757898	274328	Isolated Vacuum breaker	No 2004 documents found.	No 2004 documents found.	No 2004 documents found.	10/18/05 replaced valve assembly. 2006 remediation sampling showed no tritium in the groundwater at this location.
15	5/19/05	VB-1	20 drop per minute leak from the air release valve.	WO 00744194 and WR 00178930	336401	Isolated valve and requested repair.	No 2005 documents found.	Yes. Sampling was performed. Tritium plume was identified in 2006. Will be addressed under ATI# 435383	Will be addressed under ATI# 435383	12/18/05 replaced the vacuum breaker assembly. Tritium plume was identified around VB-1 in 2006. Being addressed under IR# 435383.
16	5/24/05	VB-6 seat	Seepage from float / seat area with one foot of water in pit.	WO 00820879	338111	Isolated leaking vacuum breaker.	No 2005 documents found.	Per IR, sampling was performed.	Will be addressed under ATI# 435383	10/19/05 rebuilt main valve and replaced air release valve. 2006 remediation sampling showed no tritium in the groundwater at this location.

#	Date	Event	Leak Size	RESPONSE						
				WR	PIF/ CR/IR	Immediate Action	Particulate Sample	Tritium Sample	10 CFR 50.75(g)	Resolution
17	1/16/06	VB-7	Bushing failure. Not significant.	WO 00883925	442540	Reduce B/D. Take samples. Evaluated for regulatory compliance, isolated valve and wrote WR	Sample analysis detected no particulate radioactivity	No detectable tritium in surface water from this leak. Prior to this leak, tritium above background & below EPA drinking water limit identified in 2006 in wells used to characterize conditions near this vacuum breaker.	Will be addressed under ATI# 435383	Pending EACE in progress. Tritium plume was identified around VB-7 in 2006, but was due to historical leakage. Remediation being addressed under IR# 435383.

Responses varied from a request for normally scheduled repairs to an immediate remediation effort. The 2000 response effectively remediated the surface spill area, but did not effectively characterize the extent of condition to allow for full remediation due to weak management review and oversight of spill response activities (**Root Cause 4**). A contributing cause common to many of the documented events is the lack of questioning attitude and oversight by Braidwood Senior Management to the radiological implications of blowdown spills. Issue ownership and follow through were lacking in all levels of management. Corrective actions 2 and 3 address training for all levels of management.

The tritium remediation plan will be tracked to completion under IR# 435383 and CAPR 2. The Braidwood Tritium Remediation Team has performed tritium characterization for the Circulating Water (CW) Blowdown (B/D) Vacuum Breakers (VBs) and performed integrity tests of the blowdown line. As of January 31, 2006, CW B/D piping acoustic testing determined that no leak above 1.0 gpm existed (minimum detectable level of testing equipment). The characterization of tritium levels in the vicinity of the vacuum breakers is described in Table 1. The station secured radioactive releases to the blowdown line on 11/23/05 and releases will remain secured until the tritium remediation team issues the final resolution under ATI# 435383-07.

b. Event timeline with events that led up to this Root Cause Investigation

October 1990

- "DRAFT" Commonwealth Edison procedure, CSG-001, "General Action Plan for Response to Unmonitored Releases and Very Low Level Radioactive Spills" was developed in 1990 but not implemented. This procedure contained guidance for mitigating intrusion of low-level radioactive spills into the groundwater. The reason the procedure was not implemented could not be identified. The failure to implement this procedure was not determined to be a root cause for three reasons. First, this procedure did not provide overall integrated guidance for spill evaluation and mitigation. Second, the reason the procedure was not implemented could not be identified. Third, no corrective action to prevent recurrence could be determined. Therefore, the lack of integrated procedural guidance to ensure proper recognition, evaluation and timely mitigation of the radiological spill events was considered a root cause (Root Cause 3) for the ineffective response to Circulating Water (CW) Blowdown (B/D) Vacuum Breaker (VB) leaks ***(Causal Factor 3, Root Cause 3).***

1991

- Illinois regulation 35 IAC 620 enacted, which places radioactivity limits on potable resource groundwater tritium concentration. This new regulation was not integrated into Company Procedures ***(Causal Factor 6).***

November 26, 1996

- Found 1" pipe from VB-1 to the air release valve failed. Estimated 250,000 gallons released to the ground.

In 1996, VB-1 had a leak of approximately 250,000 gallons due to an air release valve failure. The only documented response to this event was a work order (96111970) to isolate and repair the valve. The work control process (currently Exelon procedure WC-AA-106) had no guidance for prioritizing radiological leaks which could enter the groundwater. **(Failed Barrier 5)**. In the absence of any other recognized hazard, the current process prioritizes these work orders as a "C". Corrective action 26 will revise WC-AA-106. No documentation could be found to indicate that any actions were taken to remediate the spill or address the potential radiological concerns. Since there was no Problem Identification Form (PIF) written to document the failure, there is no record of review of this event by Braidwood Senior Management. During this team's review of this event, the team could not find any documentation of sample analysis for radioactivity.

Station actions and interviews of site personnel documented that in the past, personnel did not respond to CW B/D leaks as an offsite radioactive release. Rather, they focused on preventing potential National Pollution Discharge Elimination System (NPDES) violations. As long as the effluent (water) did not leave Exelon property, personnel did not always perceive a reason for concern, as NPDES requirements were considered met. The site personnel interviewed, that were present at the time of the 1996 event, were unaware of the Illinois regulation regarding groundwater tritium limits. Engineering walkdown Preventative Maintenance (PM) procedure (currently Exelon Braidwood procedure ER-BR-400-101) and Operations Department (OPS) walk down PM procedure (currently Braidwood procedure 0BwOS CBW-A1) did not contain any precautions or steps for addressing CW B/D spills that potentially contain tritium (**Failed Barriers 12 & 13**). Operational procedures BwOP CW-12, BwOP WX-526TI and BwOP WX-501TI had no guidance to isolate the B/D system if a known leak had occurred during a routine radiological release to the Kankakee River (**Failed Barriers 15, 16, & 17**).

No documentation was located that implied a recognition of vacuum breaker leakage impact on the requirements of the ODCM, REMP (Radiological Effluent Monitoring Program), and 10CFR50.75(g). The 1996 Annual Effluent Report did not contain an evaluation of the vacuum breaker radioactivity released and did not contain the associated evaluation of the dose to the public (IR 455079) & (CA-15).

NOTE:

As of January 2006, Elevated levels of tritium have been identified in the groundwater on Braidwood Station property close to VB-1. In one location on Braidwood property, the level of tritium was above the Illinois EPA ground water standards (20,000 picoCuries/liter). At Braidwood Station there was no site or corporate procedure for guidance on low-level radioactive spills (**Failed Barriers 4 & 6**). The Hazmat procedures (BwAP 750-4 & BwAP 1100-16) did not address radiological spills (**Failed Barriers 1 & 2**).

December, 1998

- Leak from VB-3. (See Attachment 12 for more details.)

November 20, 2000

- Leak from VB-1.

November, 2000

- Leak from VB-2. (See Attachment 12 for more details.)

December 2000

- VB-2 Root Cause Report 38237 for equipment failures was completed.

December, 2004

- Based on Operating Experience from the nuclear industry (OPEX), Braidwood Station commenced increased investigation of environmental tritium.

January, 2005

- Exelon chartered an investigation into tritium OPEX issues, with Braidwood Station providing a multi-disciplined team to support the efforts to better understand and mitigate environmental tritium issues.

March 17, 2005

- On March 17th, the Illinois Environmental Protection Agency (IEPA) notified Exelon Nuclear Corporate Environmental that they were investigating tritium concentrations in wells near Braidwood Station in preparation for the Godley public hearing on Braidwood Station's NPDES permit renewal. [The Root Cause Team could not find evidence of entry of this item into the Corrective Actions Program (Missed Opportunity)].

- The IEPA was working with Exelon Nuclear Corporate Environmental to understand why one of the Braidwood Radiological Effluent Monitoring Program (REMP) wells along the Kankakee River was indicating about 400 pCi/L concentration of tritium. [Since initial REMP sampling was commenced, the Braidwood REMP reports documented two wells along the Kankakee River with elevated tritium (within limits). One well returned to background levels when the well was redrilled (new casing)]

- The IEPA was investigating why shallow groundwater well #2 in Godley was reported to have tritium. (Exelon Corporate Environmental log documents that Exelon, an independent contractor, and the IEPA analyses could not confirm any tritium above background levels in any of the Godley, IL wells.)

March 23, 2005

The Exelon Corporate Environmental log documents that Exelon, an independent contractor, and the IEPA analyses of samples from wells in Godley Illinois did not detect any tritium above background levels.

- In preparation for the upcoming public meetings for the city of Godley, the IEPA requested (by phone) Exelon Corporate Environmental to have Braidwood Station sample for tritium at the following locations:

    1. The cooling lake discharge canal
    2. The northwest corner of the cooling lake
    3. The two monitoring wells used for the previous environmental remediation sampling on the west side of the Turbine Building.

- The IEPA was informed that Exelon installed wells to determine a groundwater gradient near the blowdown line spill at VB-2 that occurred in November 2000. These wells were installed for hydrology analysis.

- The IEPA requested that Exelon provide a sample of the offsite drainage ditch and samples from the four shallow monitoring wells that were installed in the area of the November, 2000 blowdown line leak.

- The IEPA asked Braidwood Station to sample the shallow Godley well, which was reported to be contaminated with tritium, because the Agency would like to have a recent tritium analysis on it.

March 24, 2005

- An Independent contractor sampled the following per IEPA March 23, 2005 request:

    1. The cooling lake in the discharge canal
    2. The cooling lake in the northwest corner
    3. The two monitoring wells used for the previous environmental remediation sampling (two wells closest to the Turbine Building)

    Additional Exelon samples:

    4. The cooling lake on the east-west dike approximately halfway in the middle
    5. The offsite drainage ditch
    6. The four shallow monitoring wells that were installed in the area of the November 2000 blowdown line leak

April 1, 2005

- Results (reference Braidwood Chemistry Department Sample Log) from the March 24 tritium samples taken at Braidwood Station indicated presence of tritium above background in the following locations (See Attachment 7 for Map):

  1. The cooling lake in the discharge canal - ≤ background
  2. The cooling lake in the northwest corner - ≤ background
  3. Sample point MW-4, near the November 2000 VB-2 leak – above background
     Sample point MW-6, West side of Turbine Building – above background

  Additional Exelon samples

  4. The cooling lake on the east-west dike approximately halfway in the middle - ≤ background
  5. Sample point BD-101, Braidwood drainage ditch - above background
  6. The four shallow monitoring wells that were installed in the area of the November 2000 blowdown line leak. Three were ≤ background. One was above background

  The levels identified in these samples were well below the federal standard of 20,000 picoCuries/liter (pCi/L).

- Although the tritium levels were well below federal standards, Braidwood commenced detailed sampling and investigation.

April 15, 2005

- Exelon sent Godley well results and the second sample on the drainage ditch to the IEPA. Samples had been collected on April 7, 2005:

Sample Location	Sample ID	Result
BD-101 (Drainage Ditch)	BDSW-1665	twice background
Godley Rec. Center	BDWW-1666	less than background
Godley Rec. Center	BDWW-1667	less than background

April 25, 2005

- IR 328451 was generated to identify tritium levels above background in the Braidwood drainage ditch.

May 5, 2005

- Additional samples were taken at three locations in and around the Braidwood drainage ditch in an attempt to better define the source of the tritium.

May 9, 2005

- Due to the results of the March 24, 2005 sample and confirmatory sampling of Braidwood drainage ditch, Braidwood Station expanded the sampling and investigation to focus on both surface water and groundwater sample points.

May 10, 2005

- Five shallow groundwater wells (GW-1, GW-2, TW-20, OW-32 and OW-33) were sampled (See Attachment 7 for Map). These five wells are located onsite and are positioned between the Braidwood drainage ditch and the Village of Godley. These samples were to provide more detailed information to samples previously collected on May 5. No tritium was detected above background concentrations in any of these five samples.

May 17, 2005

- A conference call was held with IEPA to exchange recent sample results and to discuss sampling in the Braidwood Station onsite wells (GW-1, GW-2, TW-20, OW-32 and OW-33) (See Attachment 7 for Map). The IEPA reported all tritium samples as less than background, which corroborated the site's results.

- The IEPA stated that they would acquire four samples from residents in Godley who live along side the drainage ditch and would analyze the samples for tritium. The Agency would provide duplicate samples for Exelon tritium analyses and would notify us when the sampling was scheduled.

May 18, 2005

- A 20 drop per minute leak from the pilot valve of vacuum breaker #1 (VB-1) was identified during a walk down by Braidwood Engineering. A sample was acquired and sent for analysis. (See Attachment 7 for Map)

May 19, 2005

- The tritium concentration in the sample of the leak catch tray at the VB-1 leak was above the IEPA standard for groundwater. (There was no evidence of leakage outside of the catch tray).

May 23, 2005

- Braidwood Station briefed the Nuclear Regulatory Commission (NRC) Inspector from the Region III Office on the drainage ditch tritium results. An overview of the sampling performed to date, along with the results of the sampling and a copy of the collated sample results, were presented to the NRC as part of the routine Offsite Dose Calculation Manual (ODCM)/Radiological Environmental Monitoring Program (REMP) inspection.

- Tritium analyses performed on five water samples collected at Braidwood Station on May 20, 2005 were less than background except for the VB-3 Pit tritium concentration which was above background (See Attachment 12 for VB-3 timeline).

June 14, 2005

- Exelon and IEPA acquired four samples from the Godley wells per the May 17 request.

June 20, 2005

- As part of the investigation to determine the source of tritium, the station received the independent contractor proposal to install monitoring wells to focus on:

    - Examining the groundwater impact in the area of VB-1 located south of the switchyard
    - Determining the movement and direction of groundwater and its relationship to surface water on both the east and north side of the Braidwood Station property

June 28, 2005

- The results of the four Godley well samples taken on June 14, showed no tritium levels above background.

July 22, 2005

- Exelon installed monitoring wells to investigate potential leakage around VB-1 and VB-3 that may be contributing to leakage in the Braidwood drainage ditch: (See Attachment 7 for Map)

  - Sample point MW-106, near the fresh water holding pond
  - Sample point MW-107, SE corner of the switchyard near VB-1
  - Sample point MW-108, east of VB-1 near the CW B/D line
  - Sample point MW-109, east of the switchyard near the Braidwood ditch

September 23, 2005

- Exelon pursued additional resources to expand the scope of the tritium investigative activities to more clearly define the source of the tritium, which had been discovered in the drainage ditch. This information was communicated by phone to the IEPA.

October 2005

- Exelon installed monitoring wells as part of an expanded scope of the tritium investigation: (See Attachment 7 for Map)

  - Sample point MW-110, north of the meteorological tower
  - Sample points MW-111, MW-112, and MW-113, north property line near Smiley Road

October 25, 2005

- Initiated IR# 390133 to address difference between historical annual liquid discharge curie content and the UFSAR description. Investigation of this difference determined that no change was required.

November 9, 2005

- Two of the four groundwater samples collected on October 19 and October 20, 2005 from the new monitoring wells exceeded the Offsite Dose Calculation Manual (ODCM) Lower Limit of Detection of 2000 pCi/L. Upon this indication, Braidwood Station assembled an Exelon Issues Management Team (OP-AA-106-101-1002) to evaluate the tritium issue.

November 22, 2005

- Nuclear Oversight (NOS) completed the ODCM, REMP, Effluent and Environmental Monitoring Audit Report, NOSA-BRW-05-08 (AR# 287718). NOS found no issues of note. NOS did not identify that the ODCM did not include Illinois State Groundwater Regulations **(Failed Barriers 28 & 29).**

November 23, 2005

- Braidwood Station terminated the use of the Circulating Water (CW) Blowdown (B/D) system for radioactive liquid releases pending resolution of this root cause investigation and appropriate corrective actions.

November 30, 2005

- Issues Management Team was formed to address tritium issues.

December 2, 2005

- Emergency Notification System (ENS) notification made to the NRC due to the notification of other government agencies (IEPA) and a press release.

January 15, 2006

- As this RCR was being finalized, a leak occurred on VB-7 due to failure of an internal guide and was documented on IR# 00442540. (See analysis section of how this issue is addressed) (See Attachment 7 for Map)

- The standing water posed no radiological concern because CW B/D radiological releases had been held in abeyance since November 23, 2005.

- The standing water in the vicinity of VB-7 was sampled for gamma radioactivity and tritium (no radioactivity detected) and evaluated for NPDES compliance. An environmental specialist verified that the leakage did not reach runoff ditches or creeks and therefore NPDES requirements were met.

- Prior to this leak, tritium above background and below the EPA drinking water limit was identified in 2006 in wells used to characterize conditions near this vacuum breaker. The source of this tritium is likely to be leakage prior to 1996 as no record of leakage subsequent to 1996 could be located.

Analysis:

The Root Cause Investigation Team interviewed personnel and reviewed the response procedures, regulations, historical documentation, and environmental impacts. An Event and Causal Factor (E&CF) Chart (Attachment 4) was utilized for Cause and Effect Analysis (Attachment 3), Change Analysis (Attachment 5) and Barrier Analysis (Attachment 2).

Unplanned Tritium releases from Braidwood Station:

The 2000 event Root Cause Report (RCR) 38237 CAPR's addressing the vacuum breaker failures were reviewed and have been determined effective in preventing major vacuum breaker failures since 2000 through the end of 2005. The purpose of the Root Cause in 2000 was to determine the cause of those failures. RCR 38237 CAPR implemented a revised preventive maintenance program for the float operated vacuum breaker valve assemblies for the CW B/D and Makeup Systems.

This Preventative Maintenance (PM) was developed to include specific intervals for inspection of valve internals and provided for periodic replacement of the valves (refer to Attachment 6 for CW B/D description). This team concludes that the RCR 38237 CAPRs have effectively prevented recurrence of the large volume leaks (as described in Table 1) caused by corroding valves that did not receive effective PMs and water hammer damage due to design configuration. Currently, daily walkdowns of the blowdown vacuum breakers are being performed to verify that no leakage is occurring.

On January 16, 2006, a leak occurred on VB-7 due to failure of an internal guide bushing and was documented on IR 00442540. EACE 442540 is performing an evaluation of this failure. The results of the EACE will be reviewed to determine if the findings in this root cause are still valid. Corrective Action 29 will track this issue. The standing water posed no radiological concern because radiological releases through the CW B/D line had been terminated pending completion of this root cause report and completion of associated corrective actions.

Root Cause Report (RCR) 38237 Corrective Action to Prevent Recurrence (CAPR) revised the system walkdown inspection requirements, including specified frequency of walkdowns and documentation and reporting of walkdown results. RCR 38237 CAPR also replaced the vacuum breaker assembly with a surge-protected configuration.

Engineering has performed an effectiveness review of these actions (ATI 38237-10) and in the three years since the initial effectiveness review, there had been no major equipment failures, which leads to the conclusion that the actions taken from the root cause report are effective in eliminating the possibility of large volume leakage due to major vacuum breaker failure.

Effectiveness of Braidwood Station response to radioactive leaks:

Interviews played an integral part in the determination of this root cause due to the lack of written information that was available from the Corrective Action Program (CAP) to this Root Cause Investigation Team for the Circulating Water (CW) Blowdown (B/D) events. The fact that some spills were not captured in the Corrective Action Program is indicative of weak management review and oversight of spill response activities (**Root Cause 4**).

A potential root cause that was considered was that draft Commonwealth Edison procedure CSG-001, "General Action Plan For Response To Unmonitored Releases And Very Low Level Radioactivity Spills" was not implemented. This procedure contained guidance for mitigating intrusion of low-level radioactive spills into the groundwater. There was no reason found as to why the procedure was not implemented.

The failure to implement this procedure was not determined to be a root cause for three reasons. First, this procedure did not provide overall integrated guidance for spill evaluation and mitigation. Second, the reason the procedure was not implemented could not be identified. Third, no corrective action to prevent recurrence could be determined. Therefore, the lack of integrated procedural guidance to ensure proper recognition, evaluation and timely mitigation of the radiological spill events was considered a root cause (Root Cause 3) for the ineffective response to Circulating Water (CW) Blowdown (B/D) Vacuum Breaker (VB) leaks ***(Causal Factor 3, Root Cause 3).***

For example, in a number of events the station addressed the NPDES concerns but no Radiation Protection (RP) individuals were engaged to address radiological concerns. Additionally, when personnel with the requisite knowledge base were involved, the lack of a pre-engineered solution that could be executed was not available. This hampered response, as each step had to be created and reviewed before actions occurred. At the time of the 2000 spill, the final remediation steps were missed under these circumstances, as independent expert reviews/challenges did not occur.

Evaluation Methods used during the investigation process for the Root Cause.

RC Tool	Why used	Advantages	Disadvantages overcome
Event and Causal Factor Chart (Att 4)	Utilized due to the complexity of the issues and actions over time.	Provide an illustration of the whole problem and contributing factors. Works very well with barrier analysis, which became necessary during the evaluation.	While time consuming, enlisted a full-time Root Cause person for the skill/experience and time to create an E&CF Chart. The large number of events verged on a CCA. However, one event was taken to represent them all and the analyses were completed utilizing that event (the 1998 event) as the template.
TapRoot	Used to assign the cause codes for individual causes of the event.	Consistent approach for more reliable cause coding.	Difficult to utilize and understand categories. Technique was used in conjunction with Trending/Coding procedure and Team input/brainstorming of causes.
Barrier Analysis (Att 2)	Used extensively, as people, physical, and administrative barriers should have prevented the issue.	Used to identify causal factors systematically, with the E&CF chart and Cause & Effect analysis to identify process weaknesses. Supports proposed corrective actions.	Utilized Team brainstorming to assure all barriers were recognized.
Change Analysis (Att 5)	Team tried to utilize to evaluate changes in procedures and regulations.	Made for a good starting point in analysis of the E&CF chart.	Information contained in this attachment was inadequate to use effectively and was therefore not utilized as an input to this root cause report.
Cause and Effect Analysis (Att 3)	Found the "Why" Stair Case instrumental due to the large number of failed barriers.	This analysis method was key in finding the common/root cause used with barrier analysis.	Utilized E&CF chart and area experts in OPS, RP, Chemistry – Environmental, and other stations as well as RA and Corporate to ensure entire background was understood for this complex problem.
Failure Modes and Effects Analysis	Not Used	Not Used	Not Used

Evaluation:

Problem Statement	**Cause** (describe the cause and identify whether it is a root cause or a contributing cause)	**Basis for Cause Determination**
Unplanned releases to the ground from unauthorized release paths.	Causal Factor 1, Root Cause 1 The root cause of the large volume leaks in 1998 and 2000 is documented in Root Cause Report (RCR) 38237, which determined that the Circulating Water (CW) Blowdown (B/D) Vacuum Breaker (VB) Valves had inadequate preventative maintenance programs and inadequate design configuration.	• Preventive Maintenance –The preventive maintenance program in year 2000 had no requirement to perform any kind of internal valve inspection or operational check and no requirement to periodically replace the valves. The vacuum breaker valves were essentially installed as run to failure components. There were no Technical Specification requirements or NRC commitments to conduct periodic maintenance. Prior to 1999, walkdowns of the blowdown system were performed annually. In July 1999, a preventive maintenance template from STANDARD NES-G-08, ComEd Performance Centered Maintenance (PCM) Templates, was adopted for application to the vacuum breaker valves. The particular template chosen is specifically applicable to spring actuated safety relief valves, and contains no discussion of applicability to float type valves. The predefine task description is "perform setpoint verification and seat leak check, or replace valve". The periodicity was set at 10 years. The template chosen was the closest match from all those available in the standard PCM template index. • Design/Application –The barrier was challenged when system operation was changed without changing the design or configuration of the vacuum breaker assemblies. Original CW blowdown system operation provided for controlling blowdown flow using valves at the river screen house, thus the system would always remain full of water. This method of operation was abandoned within the first two years of operation due to repetitive failures of the control valves. Operation thereafter provided for controlling blowdown flow using valves located in the plant near the main condensers and when flow is secured, the blowdown line would depressurize and partially drain resulting in a potential pressure surge when flow was reinitiated. Discussion with the valve manufacturer revealed that if the valves are subjected to significant pressure surges, they should be equipped with surge protection. The current configuration had no surge protection. The reason why the system operation was changed rather than correcting the material condition of the valves at the river screen house was not pursued since that decision was historical. Similarly, the reason the change was made without considering impact on the vacuum breaker design/configuration cannot be determined. • On January 16, 2006, a leak occurred on VB-7 due to failure of an internal guide bushing and was documented on IR 00442540. EACE 442540 is performing an evaluation of this failure. The results of the EACE will be reviewed to determine if the findings in this root cause are still valid. Corrective Action 29 will track this issue.

Problem Statement	**Cause** (describe the cause and identify whether it is a root cause or a contributing cause)	**Basis for Cause Determination**
	Causal Factor 2, Root Cause 2 The root cause of the small leaks, which both preceded and succeeded the 1998 and 2000 leaks, was that the need for a near zero leakage standard was not identified, due to a lack of Technical Rigor/Questionin g Attitude.	• Although the corrective actions from the 38237 Root Cause Report were effective, the report did not address "small" spills because the need for a near zero leakage standard was not known or suspected. The near zero leakage requirement was not identified in the 2000 Root Cause Report investigation due to a lack of technical rigor/questioning attitude. For details, refer to Attachment 12.
Inadequate response to unplanned releases.	Causal Factor 3, Root Cause 3: The first root cause for the ineffective response was a lack of integrated procedural guidance to ensure proper recognition, evaluation, and timely mitigation of the radiological spill events.	• After this root cause was identified, it was analyzed to determine if it was appropriate for this event. In other words, the team considered whether the "why" question had been asked enough to adequately resolve the problem. The team attempted to ask "why" and there is no clear/concrete documentation to explain why this 1990 procedure was not implemented **(Failed Barrier, FB-4)**. Utilizing TapRoot analysis process, the root cause is the most basic cause (or causes) that can be reasonably identified that management has control to correct and when corrected, will prevent (or significantly reduce the likelihood of) the issue recurring. In this event, Braidwood Senior Management has the ability to implement integrated procedural guidance to ensure the necessary knowledge of local hydrology, the impact of low-level tritium leaks, and groundwater regulations is directed to ensure consistent mitigation and remediation of future events. Thus, it was concluded that the root cause statement met the criteria of the TapRoot definition and it was appropriate for this event. • **(Failed Barriers FB 1 -17)** (See Attachment 2) CSG-001 1990 (draft only) contained guidance regarding underground transport mechanism for tritium and directions to remediate this pathway. Procedures for responding to and assessing radiological spills are either non-existent or inadequate. There was limited guidance to acknowledge 35 IAC 620 requirements or subsurface transport mechanisms to provide dose to the public. Failed barriers 1-17 address lack of integrated procedural guidance to ensure proper evaluation of the event, including knowledge of local hydrology, the impact of low-level tritium leaks, and groundwater regulations. This procedure contained instructions for mitigating intrusion of low-level radioactive spills into the groundwater. The reason the procedure was not implemented, could not be identified. Because this procedure did not provide overall integrated guidance for spill evaluation and mitigation, the failure to implement the procedure was not considered a root cause. • Therefore, the lack of integrated procedural guidance to ensure proper recognition, evaluation and timely mitigation of the radiological spill events was considered a root cause (Root Cause 3) for the ineffective response to Circulating Water (CW) Blowdown (B/D) Vacuum Breaker (VB) leaks ***(Causal Factor 3, Root Cause 3)***.

Problem Statement	Cause (describe the cause and identify whether it is a root cause or a contributing cause)	Basis for Cause Determination
Inadequate response to unplanned releases.	Causal Factor 4, Root Cause 4. A second root cause for the ineffective response was weak management review and oversight of spill response activities.	• In review of the 2000 Issues Management Team notes and other available documentation, the ineffective response from both the station and corporate levels appears to have been due to a lack of clear delineation of specific responsibilities during radiological spill response and remediation efforts. Specifically, the interface of site and corporate Radiation Protection, Chemistry and Environmental departments are not clearly defined. • Due to the cross discipline teams needed to respond /document a low level radioactive leak and the lack of one procedure to integrate the response, CAPR 4 will ensure all aspects are covered. • Original 2000 root cause (38237) was too narrowly focused. • The Issues Management Team actions had no accountability or tracking through the CAP process. • Did not properly execute issue management procedures. • Unaware of the 1991 State regulation regarding tritium limits. A Senior Corporate Manager was chosen to assemble and direct the radiological remediation team. Four Corporate procedures which direct issues management were properly entered to identify, evaluate, remediate and communicate the radiological concerns. The four procedures include: • NSP-RP-6101, "*10 CFR 50.75(g)(1) Documentation Requirements*" • CWPI-NSP-1-1, "*CAP Process Manual of Common Work Practice Instructions – Instruction on Event Response Guidelines*" • OP-AA-101-501, "*NGG Significant Event Reporting*" • OP-AA-101-503, "*NGG Issues Management*". However, no historical documentation could be located to demonstrate that the procedures (other than NSP-RP-6101) were fully executed. This indicates weak execution of the spill remediation plan by the Issues Management Team and weak Braidwood Senior Management review and oversight of spill response activities. (**Root Cause 4**) The water was pumped back into the B/D line on 11/10/00 and hydrology wells were installed in the area of the 2000 leak to characterize the local hydrology. Based on calculations and conclusions by a professional hydrologist, underground water in the area of VB-2 would take approximately 15 years to flow offsite. IDNS and IEPA were informed. Further remediation efforts were not developed after the surface water was removed. Further efforts were limited to the mechanical failure oriented Root Cause Report (RCR) 38237 and the 10 CFR 50.75(g) characterization study. The 10 CFR 50.75(g) study did not sample groundwater for tritium, even though the NSP-RP-6101 procedure and the regulation clearly state to identify all radioisotopes (**Failed Barrier 3**). This procedure will be strengthened per CA 21. As a result, the groundwater tritium went undetected until the 2005 tritium sampling discovered the groundwater tritium. This indicates weak Braidwood Senior Management review and oversight of spill response activities. (**Root Cause 4**) See timeline for 2000 event, for further substantiation of needed improvements in Braidwood Senior Management oversight.

Problem Statement	**Cause** (describe the cause and identify whether it is a root cause or a contributing cause)	Basis for Cause Determination
Inadequate response to unplanned releases.	Causal Factor 5, contributing cause. Personnel were not aware of state regulations (example: 35 IAC 620)	Personnel were not aware of state regulations (35 IAC 620) to revise procedures and training for these action levels. Additionally, those who would audit the ODCM/REMP programs were also not aware that the regulatory and procedural deficiencies existed. (See Attachment 10) If the site had been aware of the requirement, then the site would likely have been driven to properly evaluate groundwater.
	Causal Factor 6, **Notification:** Processes and procedures for communication not well defined.	(FB-30) Interviews with individuals indicated that notice to other Site Departments when an event occurred did not always occur. This was also observed through a review of the corrective actions database, which indicated that valve leakage was not always identified in CAP. In the current corrective action process at Exelon, all issues whether organizational or equipment related are entered and tracked in the corrective action program. (FB-31) Interviews with individuals indicated that a process for formal notification to the sites of State regulation changes is lacking. This was also observed through a review of applicable regulations and the lack of those regulations being consistently addressed in the ODCM, Reportability Manual, and other applicable procedures.
	Causal Factor 7, **Training:** General training has no prompt to have personnel report environmental spills for assessment of radiological conditions.	Training does not exist for Operations, Chemistry or RP personnel for specific responsibilities related to radiological spill response and assessment (reference Attachment 2)

Extent of Condition:

All Exelon Nuclear facilities are potentially affected, with added emphasis on Pressurized Water Reactors due to tritium production rates. A Nuclear Event Report (NER 428868-12) will require all Exelon Sites to take actions to research historical spills and determine if tritium remediation is required. The Nuclear Industry will be informed of the issue through a Nuclear Network Operating Experience Report (NNOE 428868-13). Other spill type (Hazardous Material) response procedures were reviewed and determined to have effective guidance through the Hazmat and Environmental programs (Attachments 2 & 8). These programs and procedures will receive further review and update to integrate radiological interfaces (CAPR 3).

Cause being addressed	Extent of Condition Review
CF-1, RC-1, CAPR-1: Significant vacuum breaker leaks in 1998 and 2000.	This condition applies to any site using a similar configuration for blowdown and radioactive release path. ATI 428868-13 was created to update the Nuclear Notification Operating Experience (NNOE) to communicate this issue to the Nuclear Industry. ATI 428868-12 was created to update the (NER) to communicate this issue to all Exelon sites. Issue Reports 00453379 and 00453387 document that Byron and LaSalle Stations have similar CW B/D and make up design configurations.
CF-2, RC-2, CAPR-2: Continuing small vacuum breaker leaks after the 2000 event.	This issue applies to all Exelon Nuclear Stations. All sites produce tritium. Pressurized Water Reactors produce a higher amount of tritium due to the usage of boron. ATI 428868-13 was created to update the Nuclear Notification Operating Experience (NNOE) to communicate this issue to the Nuclear Industry. ATI 428868-12 was created to update the Nuclear Event Report (NER) to communicate this issue to all Exelon sites. Issue Reports 00453379 and 00453387 document that Byron and LaSalle Stations have similar CW B/D and make up design configurations.
CF-3, RC-3, CAPR-4 Procedures - A lack of integrated procedural guidance to ensure proper recognition, evaluation, and timely mitigation of the spill events.	This issue applies to all Exelon Nuclear Stations. All sites produce tritium that can possibly migrate into groundwater. Pressurized Water Reactors produce a higher amount of tritium due to the usage of boron. ATI 428868-13 to update the Nuclear Notification Operating Experience (NNOE) to communicate this issue to the Nuclear Industry. ATI 428868-12 was created to update the Nuclear Event Report (NER) to communicate this issue to all Exelon sites.
CF-4, RC-4, CAPR-3 & 5: Weak management review and oversight of spill response activities.	This issue applies to all Exelon Nuclear Stations since the review and oversight is controlled by corporate procedures. Other spill type (Hazardous Material) response procedures were reviewed and determined to have effective guidance for non radiological programs (Attachment 8). These programs and procedures will receive further review and update to integrate radiological interfaces. CAPR 3 (Human Performance) and CAPR 5 (Issues Management) address these issues for all sites.
CF-5, Regulations: Personnel were not aware of State Regulations	All sites have the potential for unplanned releases. The event at Braidwood station is one example. There are numerous other nuclear industry events (OPEX) that resulted in groundwater contamination. For this reason, each site must assess the vulnerability of piping leaks and contaminating groundwater. This assessment is not limited to those plants that make liquid discharges. The concern is leakage into groundwater – not dose from liquid effluents to a defined outfall release point. Which is to say, that the ODCM does not direct routine measurements for leakage locations that may produce an exposure pathway. Issue Reports 00453379 and 00453387 document that Byron and LaSalle Stations have similar CW B/D and make up design configurations. Corrective Actions 5 through 14 will address this vulnerability at each site.
CF-6, Notification: Processes and procedures for communication not well defined.	This issue applies to all Exelon stations. CAPR 4, CAPR 5, and CA-14 will address this vulnerability at each site.
CF-7, Training: Personnel not all aware of concern with CW B/D piping and secondary side effluents being tritiated water.	This issue applies to all Exelon Nuclear Stations. ATI 428868-12 to update the Nuclear Event Report (NER) to communicate this issue to all Exelon sites.
CW B/D vacuum breaker design	Other Exelon/Amergen Nuclear sites were contacted to determine how those plants are configured for circulating water blowdown and makeup and if they have experienced any similar problems with vacuum breaker float assembly failures. Byron and LaSalle stations were the only stations confirmed to have circulating water blowdown and makeup systems that utilize vacuum breakers in their design. For circulating water blowdown and makeup systems, the extent of condition is limited to Byron and LaSalle. Reference Byron IR 453379 and LaSalle IR 453387 for the respective site OPEX review.

Risk Assessment:

Plant-specific nuclear safety risk consequence	Basis for Determination
None	There are no plant specific risks associated with this issue. There are no risks to the CW Blowdown system as a result of this issue, since the leaking (failed) vacuum breaker assembly would still function to prevent a vacuum from forming and causing damage to the CW Blowdown piping. This issue has no impact for core damage/accident mitigation. The event was reportable under Reportability Manual, SAF 1.9, News Release or Notification of Other Government Agencies.

Previous Events:

The only previous event in terms of Braidwood's response to a release of a contaminant to the nearby environment would be PIF A2000-02683, Oil in North Runoff, where waste oil from an oil separator overflow entered a ditch which formed the boundary between Braidwood Station and Godley on the Station's west side. However investigation of this event by Braidwood Station and Illinois EPA did not identify any contamination of surface or groundwater in Godley. This event is listed in the table below as part of the discussion of events found in the search of the INPO web site.

Braidwood has identified 17 leaks from the Circulating Water Blowdown piping, and three of the events, 1996, 1998, and 2000, resulted in flooding of local areas. The previous events table contains a summary of leaks identified from records in the Corrective Action Program and the Work Control Process, including the Station's response. The majority of the blowdown leaks were small (as described in Table 1) and the water does not appear to have overflowed out of the vacuum breaker vault. However, to verify this, wells were drilled in the area of each of the Vacuum Breakers and tritium samples analyzed. The areas around VB-1, VB-2, VB-3, VB-4 and VB-7 have been verified to contain tritium. The entire length of the CW blowdown line has been tested for integrity and found to be intact, with no leaks above the minimum detection limit of 1.0 gpm.

The INPO website was searched for Operating Experience (OPEX) using the terms tritium, release, offsite, and groundwater. Passport was also searched using similar parameters. There have been numerous events concerning unplanned releases to the environment at numerous sites. For the most part, the descriptions of the events do not discuss remediation or continuing monitoring, but rather a statement that no activity was released from the site or detected offsite.

One instance (Pickering, 1997) was found where the licensee attempted to remediate the tritium in the groundwater by flushing the ground with fire protection water. This did not reduce the tritium concentration in the groundwater. Only one event (Waterford, 2003) reported detectable increases in offsite tritium due to a primary to secondary tube leak.

The 2000 overflow of a Braidwood oil separator was included because of its relevance in terms of potential impact to the public and station response.

Operating Experience (OPEX) reports were reviewed. The OPEX reviewed did not reveal any missed opportunities to have prevented the events in this root cause report. Braidwood Station had no known active leaks and had no increases in any routine radiological environmental samples when low level groundwater radioactivity due to tritium was discovered.

The following are summaries of relevant OPEX events in chronological order:

Previous Events	Previous Event Review
INPO	
Oyster Creek, 1-20-81 SER 4-81	Condensate storage and radwaste transfer piping leaks resulted in underground release of radioactive liquid. No remediation was performed.
Hatch, 12-3-86, OE1905, Operating Plant Experience	124,500 gal from a spent fuel pool leak went into the storm drain system and eventually reached a swamp area within the owner-controlled property. The water discharge resulted from a loss of air to the inflatable seals used in the transfer canal between the Units 1 and 2 Spent Fuel Pools. The area was decontaminated, and no activity was detected outside Georgia Power property.
Prairie Island, 5-1-92, PNO3-92-023, Elevated levels of tritium detected in onsite well	Elevated levels of tritium (concentrations of 1, 300 to 1,500 pCi/L) were detected in an onsite groundwater well. Offsite wells sampled showed no increase in levels of tritium. No further details or follow up actions have been issued on this Preliminary Notification of Occurrence.
Dresden, 10-19-94, OE7067, Cathodic Protection System Degeneration	Degraded cathodic protection system and breached wrapping of underground piping results in through-floor pitting in both contaminated condensate storage tanks and three radwaste tanks between 1992 and 1994, through-wall pitting on the HPCI test return line and a demineralized water line, and underground fire protection piping degraded in several areas. The leakage was characterized and a remediation plan to monitor the tritium plume was implemented. No documented review of OE 7067 could be found for Braidwood Station.
Pickering A, 7-18-97, SER PD97184, Elevated Concentrations of Tritium in Groundwater	Since 1979, groundwater at the upgrader plant Pickering A (UPP-A) has had tritium levels in the surrounding groundwater that are above background. Several attempts have been made to reduce the tritium concentrations in the groundwater including pumping groundwater with low levels of tritium to the lake and flushing the area with fire protection water. Tritium concentrations in groundwater, however, remained constant. Increased tritium is due to spills and unplanned releases and not taking appropriate action to remediate the area after spills or discharges.
Braidwood, 6-25-00, PIF A2000-02683, Oil in North Runoff	Oil separator #1 overflowed into the north runoff and offsite. Root Causes were inadequate preventative maintenance of the north runoff ditch and the oil separator. Remediation and offsite sampling was performed to mitigate and assess the impact to the public.
Limerick, 2-18-02, Event Number 352-020215-1, Tritium Identified in Normal Waste Water Holding Pond and Auxiliary Boilers	Tritium concentrations of 10000 pCi/L were detected in the normal waste holding pond. There was no plant impact, no personnel exposure, and no release above regulatory limits to the environment. Groundwater monitoring is not performed.

Previous Events	Previous Event Review
Salem, 9-18-02, OE15788, Spent Fuel Pool Leakage, and OE15859 Tritium Detected in Groundwater Samples from Onsite Monitoring Wells (Follow-up to OE15788)	Leakage from the Unit 1 Spent Fuel Pool as a result of clogged telltale drains was found. To determine the affect of the leakage on site groundwater, 8 monitoring wells were installed as reported on 3-19-03. Tritium results were as high as 69,200 pCi/L in one sample, and positive results were found in 4 other wells. As reported on 7-25-03, sample results obtained from new wells indicate tritium concentrations of 3.5M pCi/L and 125K pCi/L. Gamma scans of samples from both locations detected no other radionuclides. There is no indication of any offsite release and there is no threat to the public or company employees. On 5-3-04, NRC Information Notice 2004-05: Spent Fuel Pool Leakage To Onsite Groundwater is issued describing the Salem event. Braidwood Station does not have any reasonable release paths from our spent fuel pool to the groundwater. The NER issued by Braidwood requires evaluation of all potential tritium spill paths.
Waterford, 2-28-03, OE15894, Substantial Rising Trend in Tritium Activity Measured at (REMP) Sample Location at Waterford	Primary to secondary leakage from steam generator tube/tube plug degradation resulted in an increase in secondary tritium levels and approached a reporting limit listed in the Technical Requirements Manual (TRM) for a local drainage canal.
Dresden, 7-31-04, CR248494, High Tritium Activity In Onsite Wells and Storm Drains	HPCI suction line had been leaking since Nov 2003. Up to 6M pCi/L was detected in monitoring wells and storm drains on site. Hydrology study shows the event does not affect residential wells near the site. Routine monitoring established for 1994 event had been discontinued. Remediation consists of quarterly monitoring of plume as it dissipates, verifying it does not migrate off site.
Braidwood, 12-8-04, OE19305 / OE19623, Station Challenges Effluent Quarterly Dose Limits During Unit 1 Outage	Site approaches ODCM quarterly dose limits of 7.5 mrem/unit following the A1R11 refueling outage due to failed fuel conditions. The cause of challenging the offsite dose limit is that the effluent release procedures and processes did not have limits or controls in place to account for failed fuel conditions.
Watts Bar, 2-8-05, OE20318, Onsite Groundwater Tritium Above Reporting Limits	550,000 pCi/L discovered during routine onsite environmental monitoring. No tritium has been detected in water samples from offsite monitoring locations, public drinking supplies, or the Tennessee River. Source is from a Cooling Tower Blowdown Line or previous leakage from a temporary effluent line.
Indian Point, 9-1-05, OE21506 Spent Fuel Pool Hairline Crack	Hairline cracks in the liner of the Unit 2 spent fuel pool are found. On 10-5-05 (Event Report 42014), 21100 pCi/L of tritium was detected in monitoring well MW-111 located in the Indian Point 2 transformer yard. Other wells showed negative. The sampling that was done was part of an ongoing investigation to verify and quantify previously identified leakage, potentially from the spent fuel pool. Continued sampling discovered tritium in 6 of 9 onsite wells.
Haddam Neck, 10-31-05, Event 42099	Spent Fuel Pool leakage to the site groundwater was discovered when removing soil east of the Spent Fuel Building. The quantity of water leaked is unknown. Estimates based on historic Spent Fuel Pool evaporation data indicate that the leak was small - on the order of a few gallons per day. Based on readings from down-gradient monitoring wells, there is no travel offsite.

Previous Events	Previous Event Review
EVENTS IDENTIFIED AT BRAIDWOOD STATION	**Description and review of event.**
12-5-98 - A1998-04324, CW Blowdown Vacuum Breaker Leak – pond of water found on property, with standing water in road ditch along Smiley Rd.	AR written Monday after Southern Div. PR contacted by neighbor. They sighted leaking vacuum breaker from the south was unaware of the "pond" to the north. Chemistry contacted environmental services. AR status changed to B1 due to possibly exceeding release permit limits. This incident was initiated when (name removed) was contacted about the pooled water by a local resident. (Name removed) and (name removed) investigated and noted the pool was located on station property. There was minor puddling in the adjacent ditch but this water did not run off. Environmental services were consulted and since the ponded area was restricted to station property there was no NPDES concern. The blowdown system was shut down to isolate the vacuum breaker and stop the leakage. WR 980127749 was written to repair the vacuum breaker. The work was performed over the weekend of 12/5. The station response to this event was excellent. Maintenance had this repaired in ~24 hrs. This failure had prevented the station from performing liquid releases.
11-7-00 - A2000-04281, Failed Circulating Water Blowdown Vacuum Breaker Caused Unplanned Flooding Outside the Power Block - 0CW136 CW blowdown valve was found leaking past its main seat.	The valve had been in this condition for an unknown period of time, most likely several days. The ground in the nearby area is sandy and drains quickly. The ground was saturated with water. Upon the discovery of the leak operations isolated CW blowdown on the afternoon of 11/6/2000. Draining of the piping to affect the repairs was started on the morning of 11/7/2000. The 0CW135 (manual isolation to 0CW136) and the 0CW136 CW blowdown vacuum breaker valve were replaced with new valves by 1600 hrs 11/7/2000. Once a year a visual inspection of the blowdown and make up lines is performed, including the vacuum breakers. The float in question is an internal part and cannot be inspected without disassembly of the valve. A degraded condition could be found by noting some leakage past the valve seats. This is the first failure of this type. A schedule of replacements will be proposed to the PHC by the system engineer to prevent reoccurrence. Extent Of Condition: the same/similar valve is used in several places on the CW make up and blowdown piping. Byron has a CW makeup and blowdown pipe, however it is not known if Byron has vacuum breakers and if so what type of vacuum breakers. A message was left for the Byron CW system engineer about this problem.
11-17-00 - A2000-04389 (39223), Inadequate response to 1998 CW vacuum breaker valve leak.	The station's response to a December 1998 CW vacuum breaker valve (0CW060) failure appears to have been inadequate. No evidence can be found to documenting any follow-up sampling, surveys or reporting requirements. PIF# A1998-04324 details the station' response to the 1998 leak. This issue was discovered during the present root cause investigation for the CW vacuum breaker valve failure (0CW136).
11-30-00 - A2000-04465, Slow response to implementing Event Response Guidelines/NGG Issues Management procedure.	Station was slow to implement event response guidelines, CWPI-NSP-AP-1-1, or NGG Issues Management, OP-AA-101-503, for the CW blowdown vacuum breaker failure that was discovered on 11/06/00. NGG Issues Management was not entered until 2+ days after discovery of the valve failure when rad sample results indicated detectible levels of particulate radioactivity from the spill.
6-18-01 - A2001-01806, CW B/D Valve Leaking.	Unauthorized Release Path? [#3 & 11]– 0CW060 was found seeping water from between the vacuum breaker float and the Buna-N seal. Leakage appears to be about 1 gal/2 hours. As discovered during the investigation of CR# A2000-04281, periodic maintenance of the circulating water blowdown vacuum breaker valves had not previously been up to the standards desired by the station. A campaign was initiated in Q2 2001 to repair/replace as necessary these vacuum breaker valves. When the vaults were opened, four were discovered to contain water (vaults housing 0CW060, 0CW144, 0CW075 and 0CW078). Radiological analysis of the water revealed 2 of the 4 vaults with radioactive material present in the water (0CW060 and 0CW078 showed activity).

Previous Events	Previous Event Review
7-9-01 - A2001-02016 (56710), Weaknesses Identified in Documentation of RCR For CW Blowdown Valves.	A review of a root cause report titled "Circulating Water Blowdown Line Vacuum Breaker Failure Due To Low Stress, High Cycle Fatigue, Resulting In Flooding Of Owner Controlled Property And Discharge Outside Of NPDES Approved Path" determined that there were weaknesses associated with the report documentation (reference CR# A2000-04281 and ATI# 38237). Although the report was well written, the review identified that the description of the Corrective Actions to Prevent Recurrence (CAPRS) lacked the clarity needed for mechanical maintenance to understand the full scope of work required to execute the CAPR. Furthermore, it appears that scheduling issues were not fully considered when the due dates were set.
5-4-02 - 106767, Small leak identified from 0CW060 blowdown valve assembly (VB-3)	0CW060, CW blowdown vacuum breaker, was identified as having seepage from the vent on the air release valve, (air release valve is part of the entire vacuum breaker assembly but sits adjacent to the main vacuum breaker valve). Main vacuum breaker valve appeared satisfactory, no leakage. Water level in pit was 30" from top of manhole. No evidence of leakage outside of the manhole was noticed. Water in manhole/pit appears to be a normal condition associated with groundwater infiltration into the manhole.
8-20-03 - 172376, CW Blowdown Vacuum Breaker 0CW138 has 1 gpm leak (VB-4)	Main vacuum breaker seat has 1 gpm leak. Water is draining to vacuum breaker pit only no area flooding is occurring.
8-27-03 - 173204, 0WX26T release with suspected leakage from 0CW138 VB-4.	Modification testing associated with EC336241 was performed on 8/25/03. The testing required a release to be performed from the 0WX26T release tank while blowdown flow was established at ~25,000 gpm. Seat leakage from the 0CW138 blowdown vacuum breaker most likely occurred during the time that blowdown flow was at a flow rate of 25,000 gpm. Based on field observations performed on 8/21/03 and 8/27/03 the suspected leakage from the 0CW138 during the time of the 0WX26T release was between .25 and 1 gpm, (Note: 0WS26T release occurred between 0630 and 0710 on 8/25/03, Release package L03-104.) Field observations of the 0CW138 were also performed at blowdown flow rates of between 12,000 & 14,000 gpm. These observations indicate that no leakage occurs at these lower flow rates and that the vacuum breaker appears to be open, (Note: 0CW138 open with no leakage indicates that the blowdown pipe is not completely full at the lower flow rates.)
8-29-03 - 173688, Water in Vacuum Breaker Pit for breaker 0CW060 [#3].	While performing the annual vacuum breaker surveillance we discovered water in the pit containing breaker 0CW060. WR # 00110407 was initiated.
9-11-03 - 175241, 0CM138 leaking at high CW blowdown flow rates [#4].	When CW blowdown was increased per BwOP CW-12 (to approximately 22,000 gpm, 0CW138 was discovered to be leaking at 5 drops per minute.
11-17-04 - 274328, Vacuum Breaker 0CW069 Is Leaking [#8].	While performing 0BwOS CW-A1 (CW System B/D and M/U Vacuum Breaker Inspection) vacuum breaker 0CW069 was popping/leaking. The leakage was small and contained within the vacuum breaker's valve pit. Per the Limitations and Actions of the procedure the Shift Manager and RP were notified immediately. Chemistry was notified of the potential for exceeding a limit for NPDES. System Engineering was contacted for guidance and it was determined that the 0CW068 valve would be maintained closed to isolate the vacuum breaker leakage. The System Engineer recommended that two adjacent vacuum breakers not be isolated with CW blowdown in operation. EST (37096) (Equipment status tag) was generated to document the abnormal position.

Previous Events	Previous Event Review
4-25-05 - 328451, Tritium Indicated In Samples Taken From Onsite Culvert.	Two samples results from onsite property located on the downstream side of the culvert at the old A entrance gate came back from the vendor with tritium indicated on the results. Specifically, the analysis results from Environmental Inc. Midwest Laboratory (EIML) indicated results of 539 +/-121 pCi/L tritium (sampled on 03/24/05) and 582.963 +/- 112.314 pCi/L tritium (sampled on 04/07/05).
5-18-05 - 336401, CW BD Vacuum Breaker 0CW058 Pilot Valve Leaking 20 DPM [#1].	CW BD Vacuum breaker 0CW058 pilot valve leaking 20 DPM. Need WR to repair.
5-24-05 - 338111, 0CW140 Blowdown Vacuum Breaker Valve Leaking From Seat [#6.	While performing ER-BR-400-101, 0CW140 blowdown vacuum breaker valve was observed to have continuous seepage of water from the valve float/seat area. The leakage is small enough to be contained within the vacuum breaker valve pit with approximately one foot of standing water in the pit.
9-8-05 - 371248, NRC Questions On Previous Actions With CW B/D vacuum breakers .	During NRC debrief on 8/31/05, there was discussion regarding the CW blowdown vacuum breaker, 0CW058, leakage that was identified in May 2005 (Reference IR 336401). A previous root cause was performed for vacuum breaker failures that occurred in 2000. The NRC question is: Subsequent to 0CW058 leakage identified in May 2005, were the root cause actions reviewed for adequacy? If so, what was the conclusion?
11-30-05 - 428868, Elevated Tritium Levels In Onsite Monitoring Wells.	Elevated levels of tritium have recently been identified in certain onsite groundwater sampling wells. The exact source has not been located nor has the source been determined to be active or historical.

NOTE: Review was revalidated on 02/16/06 with no new relevant events found.

Corrective Actions to Prevent Recurrence (CAPRs):

Root Cause Being Addressed	Corrective Action to Prevent Recurrence (CAPR)	Owner	Due Date
Causal Factor 1, Root Cause 1: The root cause of the significant leaks in 1998 and 2000 is documented in Root Cause Report (RCR) 38237, which determined that the Circulating Water (CW) Blowdown (B/D) Vacuum Breaker (VB) Valves had inadequate preventative maintenance programs and inadequate design configuration. Failed Barrier (FB- 20) Piping/Valves equipment failures	(CAPR 1: ATI# 38237-08, 38237-17, & 38237-18) Institute a Preventative Maintenance Program and system modifications, which are complete and have been verified to be effective in preventing major valve failures that result in large volume spills. [NOTE: On January 15, 2006, a leak occurred on VB-7 due to failure of an internal guide and was documented on IR# 442540. (See analysis section of how this issue is addressed) CA-29 will review EACE 442540 to ensure corrective actions from 2000 RCR 38237 & RCR 428868 are still effective.] Braidwood Station presently performs daily walkdowns of the blowdown vacuum breakers to verify that no leakage is occurring.	A8930TT	Completed 03/01/01
Causal Factor 2, Root Cause 2: The root cause of the small leaks, which both preceded and succeeded the 1998 and 2000 leaks, was that the need for a near zero leakage standard was not identified, due to a lack of Technical Rigor/Questioning Attitude. CF-5 Regulations/Oversight FB-33 Weak management review and oversight of spill response activities.	(CAPR 2) 1) The Braidwood Tritium Remediation Team will determine the methodology and implement the plan for future radiological releases, including leakage standards. (Note: AR 435383) (CAPR 3) 2) HU-AA-102 and HU-AA-1212, Technical Human Performance Practices and Technical Task Risk/Rigor Assessment, Pre-Job Brief, Independent Third Party Review, and Post-Job Brief procedures have been instituted to improve technical rigor, questioning attitude, and attention to detail.	1) A8901H3 2) A8923 and A8961 (approved for use at Braidwood)	1) 04/03/06 2) Completed. (Approved for use at Braidwood in 07/09/04 and 07/14/04)

Root Cause Being Addressed	Corrective Action to Prevent Recurrence (CAPR)	Owner	Due Date
Causal Factor 3, Root Cause 3: The first root cause for the ineffective response was a lack of integrated procedural guidance to ensure proper recognition, evaluation, and timely mitigation of the radiological spill events. CF-3 Procedures Failed Barrier (FB)-1 BwAP 750-4 FB-2 BwAP1100-16 FB-3 NSP-RP-6101 FB-4 RP-AA (no specific procedure) FB-6 BwOA (no specific procedure FB-12 ER-BR-400-101 FB-13 0BwOS CW-A1 FB-14 EN-AA Causal Factor 6 Notification FB-30 Notification to other site departments	(CAPR 4) Develop and implement Standard Exelon procedures to provide integrated and detailed spill and leak response requirements to ensure full compliance with State and Federal laws and regulations and integrate Exelon resources to respond to radiological leaks and spills.	NCS A8015ENV	6/20/06
Causal Factor 4, Root Cause 4. A second root cause for the ineffective response was weak management review and oversight of spill response activities. (CAPR's 3 and 5) CF-5 Regulations/Oversight FB-33 Weak management review and oversight of spill response activities.	(CAPR 3) 1) HU-AA-102 and - HU-AA-1212, Technical Human Performance Practices and Technical Task Risk/Rigor Assessment, Pre-Job Brief, Independent Third Party Review, and Post-Job Brief procedures have been instituted to improve technical rigor, questioning attitude, and attention to detail. (CAPR 5) 2) OP-AA-106-101-1002, Exelon Nuclear Issues Management, will be revised to: 1) improve Corrective Action Program (CAP) controls of Issues Management teams, 2) utilize the tools and techniques of the Exelon HU-AA-102 and HU-AA-1212, Technical Human Performance Practices and Technical Task Risk/Rigor Assessment, Pre-Job Brief, Independent Third Party Review, and Post-Job Brief procedures, 3) strengthen reporting requirements to affected station Senior Management, and 4) define affected station Senior Management responsibilities for oversight and challenge of events and issues from initial identification to final disposition.	1) A8923 and A8961 (approved for use at Braidwood) 2) A8016NGGOP	1) Completed (Approved for use at Braidwood in 07/09/04 and 07/14/04. 2) 04/21/06

Effectiveness Reviews (EFRs):

CAPR / CA being addressed	Effectiveness Review Action	Owner	Due Date
Causal Factor 1, Root Cause 1: The root cause of the significant leaks in 1998 and 2000 is documented in Root Cause Report (RCR) 38237, which determined that the Circulating Water (CW) Blowdown (B/D) Vacuum Breaker (VB) Valves had inadequate preventative maintenance programs and inadequate design configuration.	(EFR 1: 00038237-10) Perform effectiveness review of CAPR's under ATI# 00038237-7,8,10,17-20	A8930TT	Completed 05/22/2002
EFR assignment for CAPRs # 2, 3, 4, & 5: (CAPR 2) The Braidwood Tritium Remediation Team will determine the methodology and implement the plan for future radiological releases, including leakage standards. (CAPR 3) HU-AA-102 and HU-AA-1212, Technical Human Performance Practices and Technical Task Risk/Rigor Assessment, Pre-Job Brief, Independent Third Party Review, and Post-Job Brief procedures have been instituted to improve technical rigor, questioning attitude, and attention to detail. (CAPR 4) Develop and implement Standard Exelon procedures to provide integrated and detailed radiological spill and leak response requirements to ensure full compliance with state and federal laws and regulations and integrate Exelon resources to respond to radiological leaks and spills. (CAPR 5) OP-AA-106-101-1002, Exelon Nuclear Issues Management, will be revised to: 1) improve Corrective Action Program (CAP) controls of Issues Management teams, 2) utilize the tools and techniques of the Exelon HU-AA-102 and HU-AA-1212, Technical Human Performance Practices and Technical Task Risk/Rigor Assessment, Pre-Job Brief, Independent Third Party Review, and Post-Job Brief procedures, 3) strengthen reporting requirements to affected station Senior Management, and 4) define affected station Senior Management responsibilities for oversight and challenge of events and issues from initial identification to final disposition.	EFR 2 Perform effectiveness review of CAPR(s) under ATI#428868 for CAPR# 2, 3, 4, 5 .	A8932CHEM	6/20/07
MRC assignment for EFR	CA-1 Present the EFR to MRC.	A8932CHEM	6/27/07

Corrective Actions:

Cause Being Addressed	Corrective Action (CA) or Action item (ACIT)	Owner	Due Date
Causal Factor 5 Regulations/Oversight Failed Barrier (FB-33) Weak management review and oversight of radiological spill response activities.	CA-2 Develop a case study of this event. Provide initial and continuing training for appropriate Braidwood Station and Exelon Corporate Management personnel.	A8961	08/30/06
	CA-3 Generate a training request for Dynamic Learning Activity (DLA) for all Braidwood Duty Team personnel using 2000 release conditions and revised response and reporting procedures implemented in CAPR4. Create additional assignments as warranted. Report training request action determinations to STC.	A8961	07/21/06
	CA-4 Generate a training request to review other potential leaks beyond tritium to address extent of condition regarding Exelon management's control of hazardous material spills. If deficiencies are noted, write IR's to have those deficiencies addressed. Report training request action determinations to STC.	NCS A8076CHEM	05/29/06
Causal Factor 5. Regulations/ Oversight FB-27 Title 35 IAC part 620 groundwater quality	CA-5 Revise the Midwest ODCM and/or program procedures to incorporate the State of IL requirement of <20,000 pCi/L of tritium for groundwater (35 IAC 620.410.e).3)) and the State of IL requirement for non-degradation (35 IAC 620.301.a))	NCS A8076CHEM	05/29/06
	CA-6 Revise the ODCM and/or program procedures as warranted to incorporate the State of PA requirements for radioactivity in groundwater.	NCS A8076CHEM	05/29/06
	CA-7 Revise the ODCM and/or program procedures as warranted to incorporate the State of NJ requirements for radioactivity in groundwater	NCS A8076CHEM	05/29/06
	CA- 8 Clearly define to each station (extent of condition), the changes to the ODCM based on review of Illinois laws governing radioactive contamination of groundwater (potable water). Assign additional corrective actions to ensure site's ODCM reflects and implements applicable regulations.	NCS A8076CHEM	05/29/06
	CA-9 Clearly define to each station (extent of condition), the changes to the ODCM based on review of Pennsylvania laws governing radioactive contamination of groundwater (potable water). Assign additional corrective actions to ensure site's ODCM reflects and implements applicable regulations.	NCS A8076CHEM	05/29/06

Cause Being Addressed	Corrective Action (CA) or Action item (ACIT)	Owner	Due Date
Causal Factor 5. Regulations/ Oversight Failed Barrier (FB)-27 Title 35 IAC part 620 groundwater quality	CA-10 Clearly define to each station (extent of condition), the changes to the ODCM based on review of New Jersey laws governing radioactive contamination of groundwater (potable water). Assign additional corrective actions to ensure site's ODCM reflects and implements applicable regulations.	NCS A8076CHEM	05/29/06
Causal Factor 3, Procedures FB-7 LS-AA-1020 & 1110 Reportability Manual FB-8 LS-AA-1020 & 1110 Reportability Manual FB-9 LS-AA-1020 & 1110 Reportability Manual	CA-11 Corporate Regulatory Assurance to perform an extent of condition review regarding ODCM, REMP, RETS and state regulations for needed changes to the Reportability Manual and create additional actions as required. CA-12 Corporate Regulatory Assurance to revise the Reportability Manual for reporting requirements of 35 IAC 611/620 Groundwater Tritium Release Path, 20,000 pCi/L limitations, and Illinois SB241 Community Right to Know requirements.	NCS A8002RAPO NCS A8002RAPO	05/29/06 4/14/06
Causal Factor 5, Regulations/ Oversight FB-28 Corporate Oversight	CA-13 Revise CY-AA-170-000 and associated procedures to require audits of the ODCM against applicable laws and regulations at an acceptable frequency. Review the need for revision to include State regulations into Step 4.2.1 basis of the ODCM. Create additional actions as warranted.	NCS A8076CHEM	06/28/06
Causal Factor 3, Procedures FB-11 LS-AA-1020 & 1110 Reportability Manual Causal Factor 5, Regulations/Oversight FB-26 Title 35 IAC part 611 groundwater quality FB-27 Title 35 IAC part 620 groundwater quality Causal Factor 6, Notification FB-31 Notice to sites of new State Regulations	CA-14 Review the process by which the company becomes aware of new environmental laws and regulations for radiological and non-radiological issues and how they are integrated and communicated into company policies, programs, and procedures. Assign additional actions as necessary, if process changes are needed.	NCS A8015 ENV	4/14/06

Programmatic/Organizational Issues:

Programmatic and Organizational Weaknesses	Corrective Action (CA) or Action Item (ACIT)	Owner	Due Date
Causal Factor 5, Regulations/Oversight Failed Barrier (FB)-24 ODCM requires evaluation of groundwater pathway if credible FB-25 ODCM requires evaluation of groundwater pathway if credible	CA 15 Evaluate the groundwater and food crop pathway per ODCM Table 12.5-1 Section 3.a note (6). Assign additional actions as necessary, if the pathway is credible. CA 16 Revise the Site specific portions of the ODCM to incorporate the new monitoring wells as determined by the ODCM Environmental Specialist to be credible groundwater (well water) monitoring sources into the ODCM Table 11-1 Section 3.a note (6) and ODCM REMP Table 12.5-1 Section 3a Note (6).	NCS A8076CHEM NCS A8076CHEM	5/15/06 5/15/06
Causal Factor 7, Training FB-21 Certification of Chemistry personnel FB-22 Licensed and Non-licensed Operator initial and requalification training FB-23 Certification of RP/HP	CA 17 Generate TR to develop appropriate training for the RP management and technician level of knowledge regarding the CW B/D system and the radioactivity expected to be present. Refer to the Root Cause Report to be used as a case study. If the TR is rejected, report out to Senior Training Council (STC). CA 18 Generate TR to develop appropriate training for the chemistry management and technician level of knowledge regarding the CW B/D system and the radioactivity expected to be present. Refer to the Root Cause Report to be used as a case study. If the TR is rejected, report out to Senior Training Council (STC). CA 19 Generate TR to develop appropriate training for the operations personnel level of knowledge regarding the CW B/D system and the radioactivity expected to be present. Refer to the Root Cause Report to be used as a case study. If the TR is rejected, report out to Senior Training Council (STC).	A8931RP A8932CHEM A8910OPS	3/14/06 3/14/06 3/14/06
Causal Factor 3, Procedures FB-15 BwOP CW-12 FB-16 BwOP WX-526T1 FB-17 BwOP WX-501T1	CA 20 Ops to add precautions to BwOP CW-12, BwOP WX 526TI, & BwOP WX-501TI for release shutdown on leak to environment and for the release restrictions dealing with Reportability Manual Section RAD 1.21 (i.e.: 100 Ci. limit on tritium releases over a 24 hour period).	A8910OPS	5/29/06
Causal Factor 3 Procedures: FB-3, NSP-RP-6101, "10 CFR 50.75(g)(1) Documentation Requirements"	CA 21 RP manager to present to peer group changes to 50.75(g) procedure to clearly address actions necessary for tritiated water spills, including evaluation for dose assessment to the public and initiate follow-up actions as appropriate to track necessary procedure changes.	A8931RP	6/1/06

OTHER ISSUES:

Other Issues Identified During the Investigation	Corrective Action (CA) or Action Item (ACIT)	Owner	Due Date
Other issues: Alarms/ Annunciators Failed Barrier (FB)-18 Leak detection of vacuum breakers	CA-22 Braidwood System Engineering to review operation of the CW blowdown system and determine the optimum monitoring scope and frequency of inspection PM's and walk downs for the System. If applicable, identify gaps and create additional ATI's as required.	A8930TT IR435383	03/24/06
Other issues: Alarms/Annunciators FB-18 Leak detection of vacuum breakers	CA-23 Braidwood System Engineering to research and evaluate passive vacuum breaker replacement options and present findings to PHC for approval if the CW Blowdown system will be used for radwaste releases in the future. If no action is taken, present this fact to MRC.	A8930TT IR435383	07/14/06
Other issues: Alarms/ Annunciators FB-19 Alarms and Annunciators	CA-24 System Engineering to work with Design Engineering to research and evaluate viable remote monitoring instrumentation systems that can detect lower level external leakage from the blowdown system and automatically notify Braidwood Operations if the CW blowdown system will be used for radiological releases. If no action is taken, present this fact to MRC.	A8930TT IR435383	07/14/06
Other issues: Work Orders: FB-32 Model PM work orders and current work orders for B/D vacuum breakers	CA-25 RP to provide information to Work Planning so that a work standard can be created for work activities that involve potentially tritiated water. This information will be used to update PM model work orders and current work orders involving potentially tritiated water.	A8931RP	3/10/06
Causal Factor 3 Procedures FB-5 WC-AA-106 Attachment 1 implies a "B2" if increased sampling	CA-26 Corporate Work Control to implement revision of WC-AA-106 to incorporate a higher work priority for response to unplanned low-level radioactive water being released to the environment and repairs to release path monitors.	NCS A8035OUT	5/29/06
Other issues: Work Orders FB-32 Model PM work orders and current work orders for B/D vacuum breakers	CA-27 Using the information provided by RP, create a work standard to be used for work activities that involve potentially tritiated water and update PM model work orders and current work orders involving potentially tritiated water (RWP, sample for tritium, instructions for pumping tritiated water).	A8925PLN	4/10/06

Other Issues Identified During the Investigation	Corrective Action (CA) or Action Item (ACIT)	Owner	Due Date
Causal Factor 6, Notification Failed Barrier (FB)-29 NOS Audit NOSA-BRW-05-08 (AR 287718) November 22, 2005	ACIT-28 Discuss this RCR with the Corporate NOS Peer Group to evaluate changing the NOS auditing template standard for the ODCM Program. Document results and assign additional actions as required.	A8921NOA	03/28/06
Causal Factor 1, Root Cause 1	CA-29 Review EACE 00442540 to ensure corrective actions from 2000 RCR 38237 & RCR 428868 are still effective	A8930TT	03/28/06
Causal Factor 3, Procedures FB-3 NSP-RP-6101	CA-30 Review 50.75(g) files to ensure tritium and or any other isotopes are included for all blowdown vacuum breaker water events and perform 50.75(g) evaluation for all blowdown vacuum breakers not previously completed.	A8931RP	11/28/06
Other issues: Procedures FB-20 Piping/valves equipment failures	CA-31 BwOP CW-12 was revised to undo water hammer corrective actions from the 2000 root cause report. Issue to be addressed under IR 453381.	A8930TT	Per CA process
OI f1, ODCM Reportability review for environmental samples	IR 453638 Tritium Remediation Team review the reportability associated with 12.5.1.A.2 to determine applicability to the environmental groundwater sampling that is occurring as part of their investigation.	A8901H3	4/01/06
OI g1, No clear delineation of responsibilities between corporate Environmental and Chemistry for low level radioactive spills.	CA-32 Update Exelon Management Model to define responsibilities for low level radioactive spills.	NCS A8015ENV	6/20/06

Communications Plan:

Lessons Learned to be Communicated	Communication Plan Action	Owner	Due Date
Elevated tritium levels in onsite monitoring wells;	NER 1 Submit Preliminary NER (NER 1) for this event	A8932CHEM	Complete
Elevated tritium levels in onsite monitoring wells;	NNOE 1 Submit preliminary NNOE (NNOE 1) for this event.	A8932CHEM	Complete
Blowdown line, Secondary System Condensate and other low level tritium system leaks impact to State and Federal regulations for ground/drinking water.	CA 33 Create a station alignment slide that discusses the root cause and actions for station personnel when they discover liquid spills/leaks or liquid in areas where there should not be liquid.	A8932CHEM	03/14/06
Elevated tritium levels in onsite monitoring wells; Spills of liquids with low level radioactivity may impact State and Federal regulations.	NER update (NER 2) per ATI 428868-12 Submit supplemental NER (NER 2) for this event which include a requirement for all Exelon sites to; 1) Review all historical radiological spills/leaks to site property outside of the RCA. 2) Verify tritium concentrations have been determined for the radiological spills/leaks or perform sampling to determine tritium concentrations for each of the radiological spills/leaks. 3) Determine impact of spilled tritium on environment. 4) Create additional actions as warranted to insure compliance with all Federal and State regulations and laws.	A8932CHEM	03/03/06
Elevated tritium levels in onsite monitoring wells; Spills of liquids with low level radioactivity may impact State and Federal regulations	Promulgate NER 2 to Exelon Nuclear Fleet to include: Submit supplemental NER for this event which include a requirement for all Exelon sites to; 1) Review all historical radiological spills/leaks to site property outside of the RCA. 2) Verify tritium concentrations have been determined for the radiological spills/leaks or perform sampling to determine tritium concentrations for each of the radiological spills/leaks. 3) Determine impact of spilled tritium on environment	A8076CHEM	03/13/06
Elevated tritium levels in onsite monitoring wells; Spills of liquids with low level radioactivity may impact State and Federal regulations.	NNOE update (NNOE 2) per ATI 428868-13. Submit supplemental NNOE (NNOE 2) for this event	A8932CHEM	03/10/06

Root Cause Report

ATTACHMENTS

#	Title	Notes
1	Charter	Revision 1 for improved scope clarity.
2	Barrier Analysis	
3	Cause & Effect Analysis	
4	E&CF Chart	
5	Change Analysis	
6	Circ water blowdown system background information	
7	Tritium plume map	
8	Review of Exelon Hazmat spill response procedures	
9	Reportability Manual - LS-AA-1020 and LS-AA-1110	
10	Summary of Applicable State, Federal, and Offsite Dose Calculation Manual (ODCM) Regulations and Requirements for Tritium Releases to the Environment	
11	Root Cause Report Quality Checklist	
12	VB-2 and VB-3 detailed timelines	

Attachment 1

LS-AA-125-1001
Revision

Root Cause Investigation Charter (rev 1)

Tritium Release from Braidwood Station with a Potential to Affect the Public

Condition Report #: **428868**

Sponsoring Manager: Janice Kuczynski, Chemistry Manager

Team Investigator(s):

Names	Position	Commitment
Jason Eggart	Braidwood Chemistry Lead Investigator	Full Time
Tom Leffler	Root Cause Qualified Investigator	Full Time
Randy Kalb	Dresden Chemistry Investigator	Part Time
Kim Aleshire	Braidwood EP (ODCM) Investigator	Full Time
Glen Vickers	LaSalle RP Investigator	Full Time
Scott Kirkland	Quad Cities Investigator	Part Time
Jim Crawford	Braidwood Maintenance Investigator	Full Time
John Gumnick	Corporate RP (CHP) Investigator	Part-Time
Mike Miller	Braidwood Operations	Part Time
Jeff Burkett	Braidwood Operations	Part Time
Dan Stroh	Braidwood Engineering	Full-Time
Scott Sklenar	Hydrologist	Part-Time

Scope:

The scope of the root cause investigation is twofold:

The first focus of this root cause team is to determine the root cause(s) of the Tritium releases from Braidwood Station, which, although low level, had a potential to affect the public. This causal determination should include the large volume leaks, which occurred in 1998 and in 2000, as well as the smaller volume leaks, which both followed and preceded the 1998 and 2000 leaks. The responsibility for identifying and operationalizing corrective actions to prevent future unacceptable tritium releases to the environment is being addressed by the Braidwood Tritium Remediation Team under AR 435383.

This root cause team remains responsible for identifying corrective actions to address organizational weaknesses contributing to or causing the releases described above.

The second focus of this root cause team is to evaluate the effectiveness of Braidwood's response to the circulating water Blowdown leaks, which deposited tritiated water on the ground during 1998 and 2000 as well as during the smaller volume leaks, which both followed and preceded the 1998 and 2000 leaks. If this evaluation determines that Braidwood's response actions were not effective, this root cause team will determine the root cause and appropriate corrective actions for those ineffective response actions. The investigation will review response procedures, regulations, environmental impacts, and managerial effectiveness. As part of this second focus item, the team will review the response to known spills in 1998, 2000 and similar IRs. A review of year 2000 Root Cause corrective action effectiveness will be performed. Specifically, the team will look for any evidence that the actions to prevent recurrence were not effective. An E&CF Chart will be utilized for Change Analysis and Barrier Analysis. Tap Root Analyses will also be utilized. To accomplish a timely report delivery, support will be required as noted above in Engineering, Hydrology, Maintenance, Operations, Offsite Dose Assessment, and Technical Writing.

The responsibility for remediating the existing condition of detectable tritium in groundwater on and in the vicinity of Braidwood Station is not the responsibility of this root cause team. Remediation of the existing condition of detectable tritium in groundwater on and in the vicinity of Braidwood Station is being addressed by the Braidwood Tritium Remediation Team under AR 435383.

Interim Corrective Actions:

As described above, an Issues Management Team (the Braidwood Tritium Remediation Team) has been formed to manage the recovery.
Additional Sampling is being performed and analyzed to fully define the affected areas.
The discharge piping is being reviewed for integrity.
Remediation plans will be developed and implementation initiated.
The Braidwood Tritium Remediation Team will maintain communications with Exelon, Regulatory personnel, the public, and INPO.

Attachment 1

Root Cause Report Milestones:

1.	Event Date	(11/30/05)
2.	Screening Date	(12/07/05)
3.	Completion of Charter (2 Days from MRC) [-03]	(12/09/05)
3a.	Completion of Charter revision	(02/08/06)
4.	Status Briefing for Charter [-14]	(12/14/05)
5.	Two Week Update & Draft RCR for Reviews [-07]	(12/21/05)
6.	MRC Update & Draft RCR for Reviews [-08]	(12/28/05)
7.	CAPCo Reviews of RCR [-15]	(12/29/05)
8.	Collegial Reviews of RCR [-15]	(12/29/05)
9.	MRC Update & Draft RCR for Reviews [-09]	(01/04/06)
10.	Sponsoring Manager Report Approval [-14]	(01/04/06)
11.	Root Cause delivered to PORC	(01/24/06)
12.	Review by PORC [-05]	(01/26/06)
13.	Revised Root Cause Report delivered to PORC	(02/20/06)
14.	Revised Root Cause Report Reviewed by PORC	(02/22/06)
15.	Final Root Cause Investigation Due Date [-04]	(02/23/06)

Prepared By:	Tom Leffler, Root Cause Qualified Investigator	02/06/06
	(Name)	(Date)
Approved By:	Carl B. Dunn, Training Director	02/08/06
	For (Sponsoring Manager)	(Date)

Attachment 2

Barrier Analysis

Failed or ineffective barrier	How Barrier Failed	Why Barrier Failed	Corrective action to Restore Barrier to Effectiveness
Procedures	**CF 3**		
BwAP 750-4 Failed Barrier 1 (FB-1)	- Hazmat was not entered - Procedure does not prompt radiological response	Lack of knowledge of Title 35 IAC part 620 groundwater quality	- Develop and implement Standard Exelon procedures to provide integrated and detailed spill and leak response requirements to ensure full compliance with state and federal laws and regulations and integrate Exelon resources to respond to radiological leaks and spills. (CAPR 4) - See Training Failed Barrier actions
BwAP1100-16 (FB-2)	- Hazmat was not entered - Procedure does not prompt radiological response	Lack of knowledge of Title 35 IAC part 620 groundwater quality	-Develop and implement Standard Exelon procedures to provide integrated and detailed spill and leak response requirements to ensure full compliance with state and federal laws and regulations and integrate Exelon resources to respond to radiological leaks and spills. (CAPR 4) -See Training Failed Barrier actions
NSP-RP-6101 (FB-3)	50.75(g) does not clearly address tritium	Lack of knowledge of Title 35 IAC part 620 groundwater quality	- Develop and implement Standard Exelon procedures to provide integrated and detailed spill and leak response requirements to ensure full compliance with state and federal laws and regulations and integrate Exelon resources to respond to radiological leaks and spills. (CAPR 4) -RP manager to present to peer group changes to 50.75(g) procedure to clearly address actions necessary for tritiated water spills, including evaluation for dose assessment to the public and initiate follow-up actions as appropriate to track necessary procedure changes. (CA-21) -Review 50.75(g) files to ensure tritium and or any other isotopes are included for all blowdown vacuum breaker water events and perform 50.75(g) evaluation for all blowdown vacuum breakers not previously completed. (CA-30) -See Training Failed Barrier actions

Attachment 2

Barrier Analysis

Failed or ineffective barrier	How Barrier Failed	Why Barrier Failed	Corrective action to Restore Barrier to Effectiveness
RP-AA (FB-4)	No guidance for low level spills	Lack of knowledge of Title 35 IAC part 620 groundwater quality	Develop and implement Standard Exelon procedures to provide integrated and detailed spill and leak response requirements to ensure full compliance with state and federal laws and regulations and integrate Exelon resources to respond to radiological leaks and spills. (CAPR-4) - See Training Failed Barrier actions
WC-AA-106 Attachment 1 implies a "B2" if increased sampling (FB-5)	WC called issues "C", not recognizing that sampling for tritium would be required	Lack of knowledge of Title 35 IAC part 620 groundwater quality	- See Training Failed Barrier actions - Corporate Work Control to implement revision of WC-AA-106 to incorporate a higher work priority for response to low level radioactive water being released to the environment. (CA-26)
BwOA (Radiological spill procedure does not exist) (FB-6)	No guidance for low level spills	Lack of knowledge of Title 35 IAC part 620 groundwater quality	Develop and implement Standard Exelon procedures to provide integrated and detailed spill and leak response requirements to ensure full compliance with state and federal laws and regulations and integrate Exelon resources to respond to radiological leaks and spills. (CAPR-4) - See Training Failed Barrier actions
LS-AA-1020 & 1110 Reportability Manual (FB-7)	Does not reflect ODCM REMP/RETS reporting requirements	Lack of knowledge of Title 35 IAC part 620 groundwater quality	-Corporate Regulatory Assurance to perform an extent of condition review regarding ODCM, REMP, RETS and state regulations for needed changes to the Reportability Manual and create additional actions as required. (CA-11) -Corporate Regulatory Assurance to revise the Reportability Manual for reporting requirements of 35 IAC 611/620 Groundwater Tritium Release Path, 20,000 pCi/L limitations, and Illinois SB241 Community Right to Know requirements. (CA-12) - See Training Failed Barrier actions

Barrier Analysis

Failed or ineffective barrier	How Barrier Failed	Why Barrier Failed	Corrective action to Restore Barrier to Effectiveness
LS-AA-1020 & 1110 Reportability Manual (FB-8)	Does not reflect 35 IAC 620 Groundwater Tritium Release Path, 20,000 pCi/L limitations	Lack of knowledge of Title 35 IAC part 620 groundwater quality	-Corporate Regulatory Assurance to perform an extent of condition review regarding ODCM, REMP, RETS and state regulations for needed changes to the Reportability Manual and create additional actions as required. (CA-11) -Corporate Regulatory Assurance to revise the Reportability Manual for reporting requirements of 35 IAC 611/620 Groundwater Tritium Release Path, 20,000 pCi/L limitations, and Illinois SB241 Community Right to Know requirements. (CA-12) - See Training Failed Barrier actions
LS-AA-1020 & 1110 Reportability Manual (FB-9)	ENV 3.26 does not clearly warn of tritium groundwater quality standards	Lack of knowledge of Title 35 IAC part 620 groundwater quality	-Corporate Regulatory Assurance to perform an extent of condition review regarding ODCM, REMP, RETS and state regulations for needed changes to the Reportability Manual and create additional actions as required. (CA-11) -Corporate Regulatory Assurance to revise the Reportability Manual for reporting requirements of 35 IAC 611/620 Groundwater Tritium Release Path, 20,000 pCi/L limitations, and Illinois SB241 Community Right to Know requirements. (CA-12) - See Training Failed Barrier actions
LS-AA-1020 & 1110 Reportability Manual (FB-10)	RAD 1.21, 100Ci tritium 24h release limitation not checked	Lack of knowledge of tritium amounts released	- See Training Failed Barrier actions
LS-AA-1020 & 1110 Reportability Manual (FB-11)	SAF 1.9 New Right to Know legislation not reflected.	No program for review and promulgation of new laws.	Review the process by which the company becomes aware of new environmental laws and regulations for radiological and non-radiological issues and how they are integrated and communicated into company policies, programs, and procedures. Assign additional actions as necessary, if process changes are needed. (CA-14)

Attachment 2

Barrier Analysis

Failed or ineffective barrier	How Barrier Failed	Why Barrier Failed	Corrective action to Restore Barrier to Effectiveness
ER-BR-400-101, Engineering Walkdown PM Procedure (FB-12)	No precaution for tritium groundwater concern	Lack of knowledge of Title 35 IAC part 620 groundwater quality	-Develop and implement Standard Exelon procedures to provide integrated and detailed spill and leak response requirements to ensure full compliance with state and federal laws and regulations and integrate Exelon resources to respond to radiological leaks and spills. (CAPR-4) - See Training Failed Barrier actions
0BwOS CW-A1 OPS Walkdown PM Procedure (FB-13)	No precaution for tritium groundwater concern	Lack of knowledge of Title 35 IAC part 620 groundwater quality	Develop and implement Standard Exelon procedures to provide integrated and detailed spill and leak response requirements to ensure full compliance with state and federal laws and regulations and integrate Exelon resources to respond to radiological leaks and spills. (CAPR-4) - See Training Failed Barrier actions
EN-AA-Environmental procedures (FB-14)	No guidance for radiological spills that can get to drinking water supplies	Lack of knowledge of Title 35 IAC part 620 groundwater quality	-Develop and implement Standard Exelon procedures to provide integrated and detailed spill and leak response requirements to ensure full compliance with state and federal laws and regulations and integrate Exelon resources to respond to radiological leaks and spills. (CAPR-4) -See training failed actions barrier actions
BwOP CW-12 (FB-15)	No shutdown precautions during a release for a leak in the blowdown system	Lack of knowledge of Title 35 IAC part 620 groundwater quality	- Ops to add precautions to BwOP CW-12, BwOP WX-526TI, & BwOP WX-501TI for release shutdown on leak to environment and for the release restrictions dealing with Reportability Manual Section RAD 1.21 (i.e.: 100 Ci. limit on tritium releases over a 24 hour period). (CA-20) -See training failed barrier actions
BwOP WX-526TI, (FB-16)	No shutdown precautions during a release for a leak in the blowdown system	Lack of knowledge of Title 35 IAC part 620 groundwater quality	- Ops to add precautions to BwOP CW-12, BwOP WX-526TI, & BwOP WX-501TI for release shutdown on leak to environment and for the release restrictions dealing with Reportability Manual Section RAD 1.21 (i.e.: 100 Ci. limit on tritium releases over a 24 hour period). (CA-20) -See training failed barrier

Barrier Analysis

Failed or ineffective barrier	How Barrier Failed	Why Barrier Failed	Corrective action to Restore Barrier to Effectiveness
BwOP WX-501TI (FB-17)	No shutdown precautions during a release for a leak in the blowdown system	Lack of knowledge of Title 35 IAC part 620 groundwater quality	- Ops to add precautions to BwOP CW-12, BwOP WX-526TI, & BwOP WX-501TI for release shutdown on leak to environment and for the release restrictions dealing with Reportability Manual Section RAD 1.21 (i.e.: 100 Ci. limit on tritium releases over a 24 hour period). (CA-20) - See training failed barrier actions
Alarms/ Annunciators	**Other Issue "a"**		
Leak detection on vacuum breakers (FB-18)	Only performed annually at the time of the 1998 event. Recently performed on semi-annual basis. Currently (Since Sept. 2005) performed monthly	Not often enough to detect leaks. System has inherent suspended materials in the CW, which can cause the valves to stick open, allowing tritiated water to be released.	Braidwood System Engineering to review operation of the CW Blowdown system and determine the optimum monitoring scope nd frequency of inspection PM's and walk downs for the ystem. If applicable, identify gaps and create additional ATI's s required (CA-22) -Braidwood System Engineering to research and evaluate passive vacuum breaker replacement options and present findings to PHC for approval if the CW Blowdown system will be used for radiological releases in the future (CA-23)
Alarms and annunciators (FB-19)	Did not alarm	Did not exist. Neither the Operations Department, which is responsible for operating and monitoring the CW B/D System, nor Plant Engineering, which has responsibility for managing the CW B/D System, recognized the need for, nor did they pursue installation of a remote detection system for each vacuum breaker. Such a system may have allowed earlier detection and isolation of the leaks described in Table 1, which could have reduced environmental impact.	System Engineering to work with Design Engineering to research and evaluate viable remote monitoring instrumentation systems that can detect lower level external leakage from the blowdown system and automatically notify Braidwood Operations if the CW blowdown system will be used for radiological releases. (CA-24)

Barrier Analysis

Failed or ineffective barrier	How Barrier Failed	Why Barrier Failed	Corrective action to Restore Barrier to Effectiveness
Preventative maintenance/ design configuration	**CF-1**		
Piping/Valves equipment failures (FB-20)	Water hammer events	Changed BwOP-CW12 and created a water hammer issue	BwOP CW-12 revised to mitigate water-hammer – revision 14. **(Completed, 01/19/01)**. Corrective actions reversed by a subsequent revision. Corrective actions to be addressed under IR 453381. (CA-31)
	Inadequate preventative maintenance programs and inadequate design configuration	▪ Lack of preventative maintenance program for these valves ▪ Valves were not designed to handle the water hammer events	Institute a Preventative Maintenance Program and system modifications, which are complete and have been verified to be effective in preventing major valve failures that result in large volume spills. **(CAPR 1)**
Training	**CF-7**		
Certification of Chemistry personnel (FB-21)	No training on a response to a liquid radiological spill for requirements of Title 35 IAC part 620 groundwater quality.	Did not know Title 35 IAC part 620 groundwater Tritium concentration limits	Generate TR to analyze the chemistry management and technician level of knowledge regarding the CW B/D system and the radioactivity expected to be present. Refer to the Root Cause Report to be used as a case study. (CA-18)

Attachment 2
Page 7 of 11

Barrier Analysis

Failed or ineffective barrier	How Barrier Failed	Why Barrier Failed	Corrective action to Restore Barrier to Effectiveness
Licensed and Non-licensed Operator initial and requalification training **(FB-22)**	No Environmental spill training for low level radioactive liquids	Did not know Title 35 IAC part 620 groundwater quality	Generate TR to analyze the operations personnel level of knowledge regarding the CW B/D system and the radioactivity expected to be present. Refer to the Root Cause Report to be used as a case study. (CA-19)
Certification of RP/HP **(FB-23)**	Lack of cert guide for low level radioactive liquid spills	Did not know Title 35 IAC part 620 groundwater quality.	Generate TR to analyze the RP management and technician level of knowledge regarding the CW B/D system and the radioactivity expected to be present. Refer to the Root Cause Report to be used as a case study. (CA-17)
Regulations	**CF-5**		
ODCM requires evaluation of groundwater pathway if credible **(FB-24)**	Braidwood has demonstrated a credible pathway	Did not know Title 35 IAC part 620 groundwater tritium concentration limits	Evaluate the groundwater and food crop pathway per ODCM Table 12.5-1 Section 3.a note (6). Assign additional actions as necessary, if the pathway is credible. (CA-15)
ODCM requires evaluation of groundwater pathway if credible **(FB-25)**	Braidwood has demonstrated a credible pathway	Did not know Title 35 IAC part 620 groundwater Tritium concentration limits	Revise the Site specific portions of the ODCM to incorporate the new monitoring wells as determined by the ODCM Environmental Specialist to be credible groundwater (well water) monitoring sources into the ODCM Table 11-1 Section 3.a note (6) and ODCM REMP Table 12.5-1 Section 3a Note (6).groundwater. (CA-16)
Title 35 IAC part 611 groundwater quality **(FB-26)**	ODCM does not reflect state groundwater requirements	Did not know Title 35 IAC part 611 groundwater quality	Review the process by which the company becomes aware of new environmental laws and regulations for radiological and non-radiological issues and how they are integrated and communicated into company policies, programs, and procedures. Assign additional actions as necessary, if process changes are needed. (CA-14)

Barrier Analysis

Failed or ineffective barrier	How Barrier Failed	Why Barrier Failed	Corrective action to Restore Barrier to Effectiveness
Title 35 IAC part 620 groundwater quality (FB-27)	ODCM does not reflect state groundwater requirements.	Did not know Title 35 IAC part 620 groundwater quality standards.	Revise the Midwest ODCM and/or program procedures to incorporate the State of IL requirement of <20,000 pCi/L of tritium for groundwater (35 IAC 620.410.e).3)) and the State of IL requirement for non-degradation (35 IAC 620.301.a)) (CA-5) Revise the ODCM and/or program procedures as warranted to incorporate the State of PA requirements for radioactivity in groundwater. (CA-6) Revise the ODCM and/or program procedures as warranted to incorporate the State of NJ requirements for radioactivity in groundwater (CA-7) Clearly define to each station (extent of condition), the changes to the ODCM based on review of Illinois laws governing radioactive contamination of groundwater (potable water). Assign additional corrective actions to ensure site's ODCM reflects and implements applicable regulations. (CA-8) Clearly define to each station (extent of condition), the changes to the ODCM based on review of Pennsylvania laws governing radioactive contamination of groundwater (potable water). Assign additional corrective actions to ensure site's ODCM reflects and implements applicable regulations. (CA-9) Clearly define to each station (extent of condition), the changes to the ODCM based on review of New Jersey laws governing radioactive contamination of groundwater (potable water). Assign additional corrective actions to ensure site's ODCM reflects and implements applicable regulations. (CA-10) Review the process by which the company becomes aware of new environmental laws and regulations for radiological and non-radiological issues and how they are integrated and communicated into company policies, programs, and procedures. Assign additional actions as necessary, if process changes are needed. (CA-14)

Barrier Analysis

Failed or ineffective barrier	How Barrier Failed	Why Barrier Failed	Corrective action to Restore Barrier to Effectiveness
Corporate Oversight CY-AA-170-000, CY-AA-170-100, CY-AA-170-1000, CY-AA-170-200, CY-AA-170-2000, CY-AA-170-2000, CY-AA-170-300, CY-AA-170-3100. **(FB-28)**	Did not uncover 2 missing State regulations or the state groundwater tritium concentration issue.	Corporate audits did not check program to sufficient detail	Revise CY-AA-170-000 and associated procedures to require audits of the ODCM against applicable laws and regulations at an acceptable frequency. Review the need for revision to include State regulations into Step 4.2.1 basis of the ODCM. Create additional actions as warranted. (CA-13)
Notification	**CF-6**		
NOS Audit NOSA-BRW-05-08 (AR 287718) November 22, 2005 **(FB-29)**	Did not uncover two (2) missing state regulations or the state groundwater tritium concentration issue	NOS Audit Plan did not check program to sufficient detail, did not verify ODCM met applicable state regulations	Discuss this RCR with the Corporate NOS Peer Group to evaluate changing the NOS auditing template standard for the ODCM Program. Document results and assign additional actions as required. (ACIT-28)
Notice to other Site Departments when an event occurred **(FB-30)**	Did not always inform all affected parties	No procedure to assure consistent approach to leaks/spills	Develop and implement Standard Exelon procedures to provide integrated and detailed spill and leak response requirements to ensure full compliance with state and federal laws and regulations and integrate Exelon resources to respond to radiological leaks and spills. (CAPR-4)

Barrier Analysis

Failed or ineffective barrier	How Barrier Failed	Why Barrier Failed	Corrective action to Restore Barrier to Effectiveness
Notice to sites of new State Regulations (FB-31)	Sites not informed of new Illinois SB241, Community Right to Know	Program not robust	Review the process by which the company becomes aware of new environmental laws and regulations for radiological and non-radiological issues and how they are integrated and communicated into company policies, programs, and procedures. Assign additional actions as necessary, if process changes are needed. (CA-14)
Work Orders	**Other Issue "b"**		
Model PM work orders and current work orders for B/D vacuum breakers (FB-32)	Failed to have RP sampling of leaks and how to properly dispose of liquids not in work order instructions.	Did not know Title 35 IAC part 620 groundwater quality	- RP to provide information to Work Planning so that a work standard can be created for work activities that involve potentially tritiated water. This information will be used to update PM model work orders and current work orders involving potentially tritiated water. (CA-25) - Using the information provided by RP, create a work standard to be used for work activities that involve potentially tritiated water and update PM model work orders and current work orders involving potentially tritiated water (RWP, sample for tritium, instructions for pumping tritiated water). (CA-27)

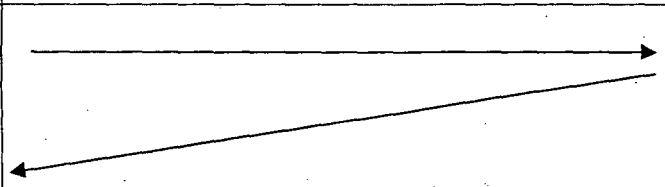
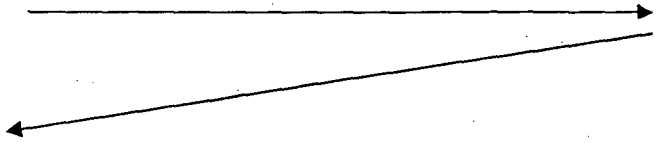
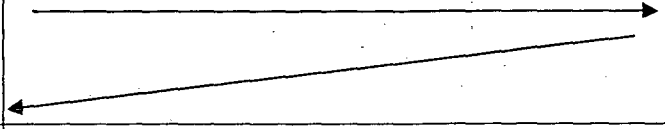
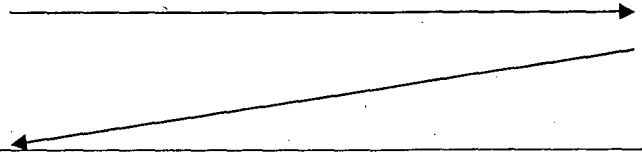
Attachment 2
Page 11 of 11

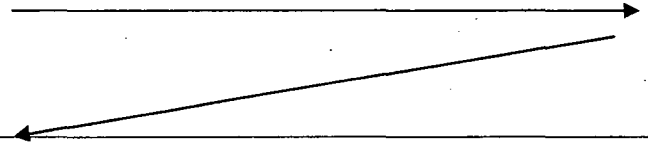
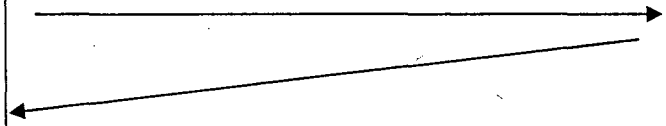
Barrier Analysis

Failed or ineffective barrier	How Barrier Failed	Why Barrier Failed	Corrective action to Restore Barrier to Effectiveness
Oversight	**CF-4 and CF-2**		
Weak management review and oversight of spill response activities. **(FB-33)**	**CF4:** Braidwood Senior Management did not question the radiological impact of all leaks that had happened.	Lack of questioning attitude regarding unplanned spills from the blowdown system.	OP-AA-106-101-1002, Exelon Nuclear Issues Management, will be revised to: 1) improve Corrective Action Program (CAP) controls of Issues Management teams, 2) utilize the tools and techniques of the Exelon HU-AA-102 and HU-AA-1212, Technical Human Performance Practices and Technical Task Risk/Rigor Assessment, Pre-Job Brief, Independent Third Party Review, and Post-Job Brief procedures, 3) strengthen reporting requirements to affected station Senior Management, and 4) define affected station Senior Management responsibilities for "cradle to grave" oversight and challenge of events and issues. (CAPR 5)
	CF2: Lack of questioning attitude for low level radiological spills. The need for a near zero leakage standard was not identified.	Did not know Title 35 IAC part 620 groundwater Tritium concentration limits	The Braidwood Tritium Remediation Team will determine the methodology and implement the plan for future radiological releases, including leakage standards. (CAPR 2) Develop a case study of this event. Provide initial and continuing training for MRC/SOC members. (CA-2) Evaluate conducting Dynamic Learning Activity (DLA) on a Duty Team basis using 2000 release conditions and revised response and reporting procedures implemented in CAPR 4. Create additional assignments as warranted. (CA-3) Review other potential leaks beyond tritium to address extent of condition regarding Exelon management's control of hazardous material spills. If deficiencies are noted, write IR's to have those deficiencies addressed. (CA-4)

Attachment 3A

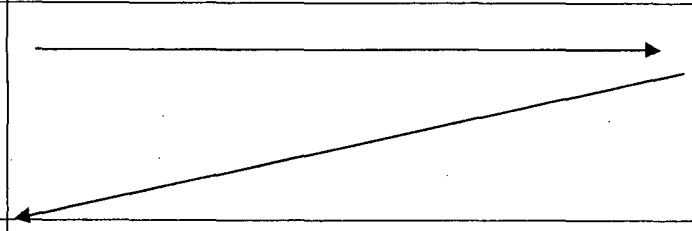
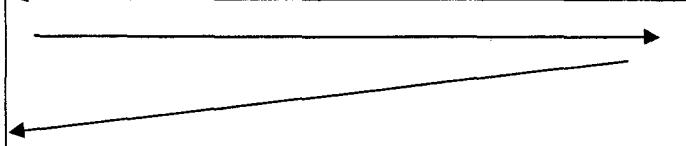
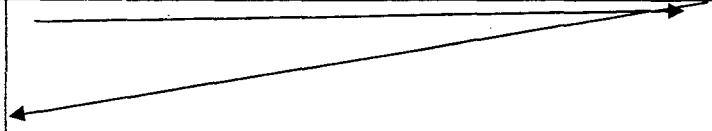
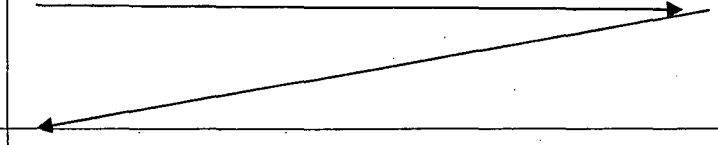
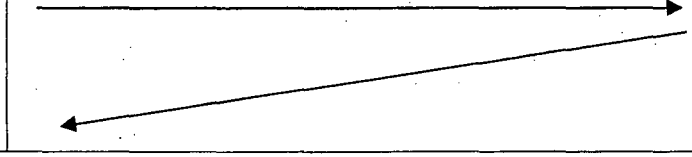
–Cause & Effect Analysis

Effect / Symptom	Why	Cause / Reason
Vacuum breaker leaks occurred after 2000		Small leaks were never considered to be a problem
Small leaks were never considered to be a problem		2000 Root Cause Team only addressed major failures
2000 Root Cause Team only addressed major failures		The 2000 charter was to determine the major failures
The 2000 charter was to determine the major failures		The charter was narrowly scoped due to two teams were developed to perform the Root Cause and Radiological spill Response
The charter was narrowly scoped due to two teams were developed to perform the Root Cause and Radiological spill Response		Was not considered a problem as small leaks did not leave the site

Was not considered a problem as small leaks did not leave the site		People did not know the 1991 statute for groundwater.
People did not know the 1991 statute for groundwater.		The need for a near zero leakage standard was not identified, due to a lack of Technical Rigor/Questioning Attitude (**Root Cause 2**).
The need for a near zero leakage standard was not identified, due to a lack of Technical Rigor/ Questioning Attitude (**Root Cause 2**).		At this time the HU-AA-1212 and 102 procedures did not exist.(CAPR 3)

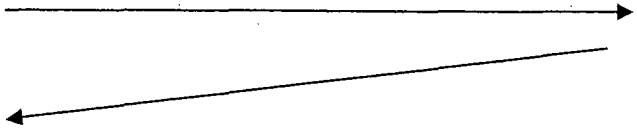
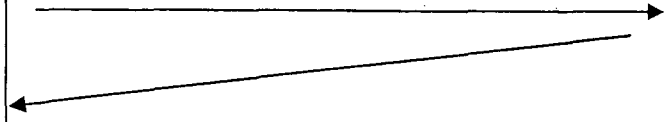
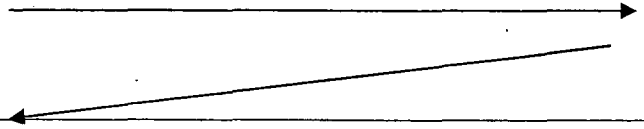
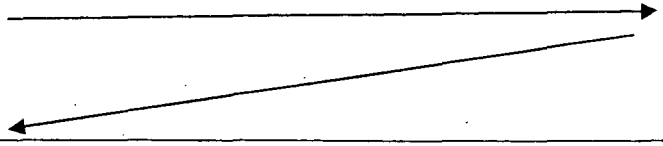
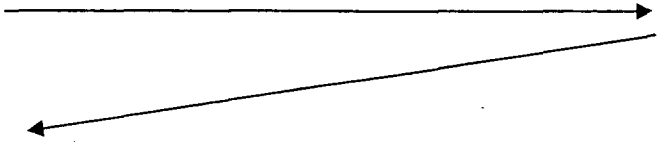
Attachment 3B

—Cause & Effect Analysis

Effect / Symptom	Why	Cause / Reason
Tritium found off site		Inadequate response
Inadequate response		Personnel not aware of the B/D water Tritium exceeding groundwater limits. Belief that release package authorized unrestricted release to environment.
Personnel not aware of the B/D water Tritium exceeding limits. Belief that release package authorized unrestricted release to environment.		Personnel not aware of the IEPA tritium limit requirements for groundwater
Personnel not aware of the IEPA tritium limit requirements for groundwater		Knowledge deficiency
Knowledge deficiency		No integrated procedural guidance for groundwater radiological spills (Root Cause 3)

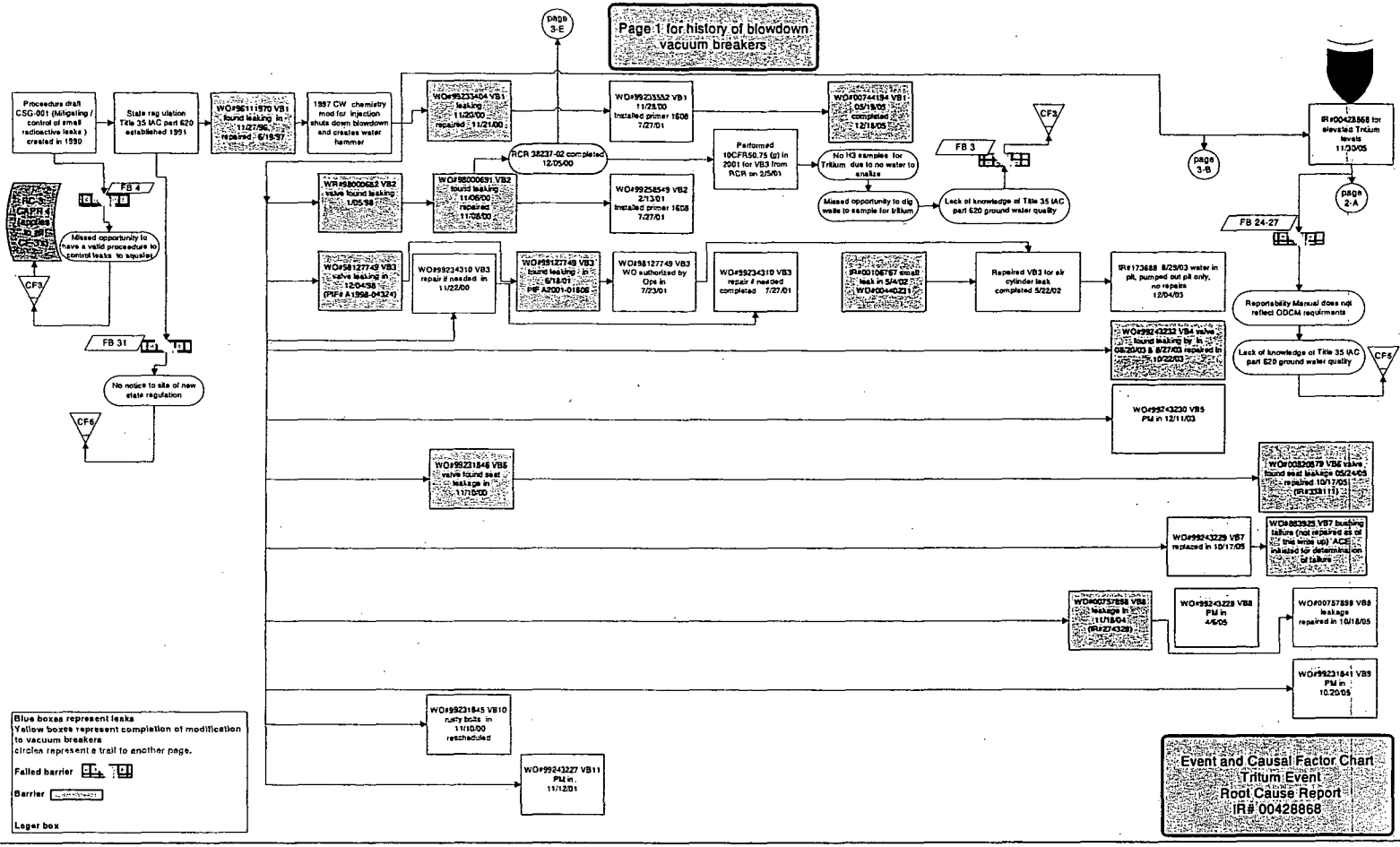
Attachment 3C

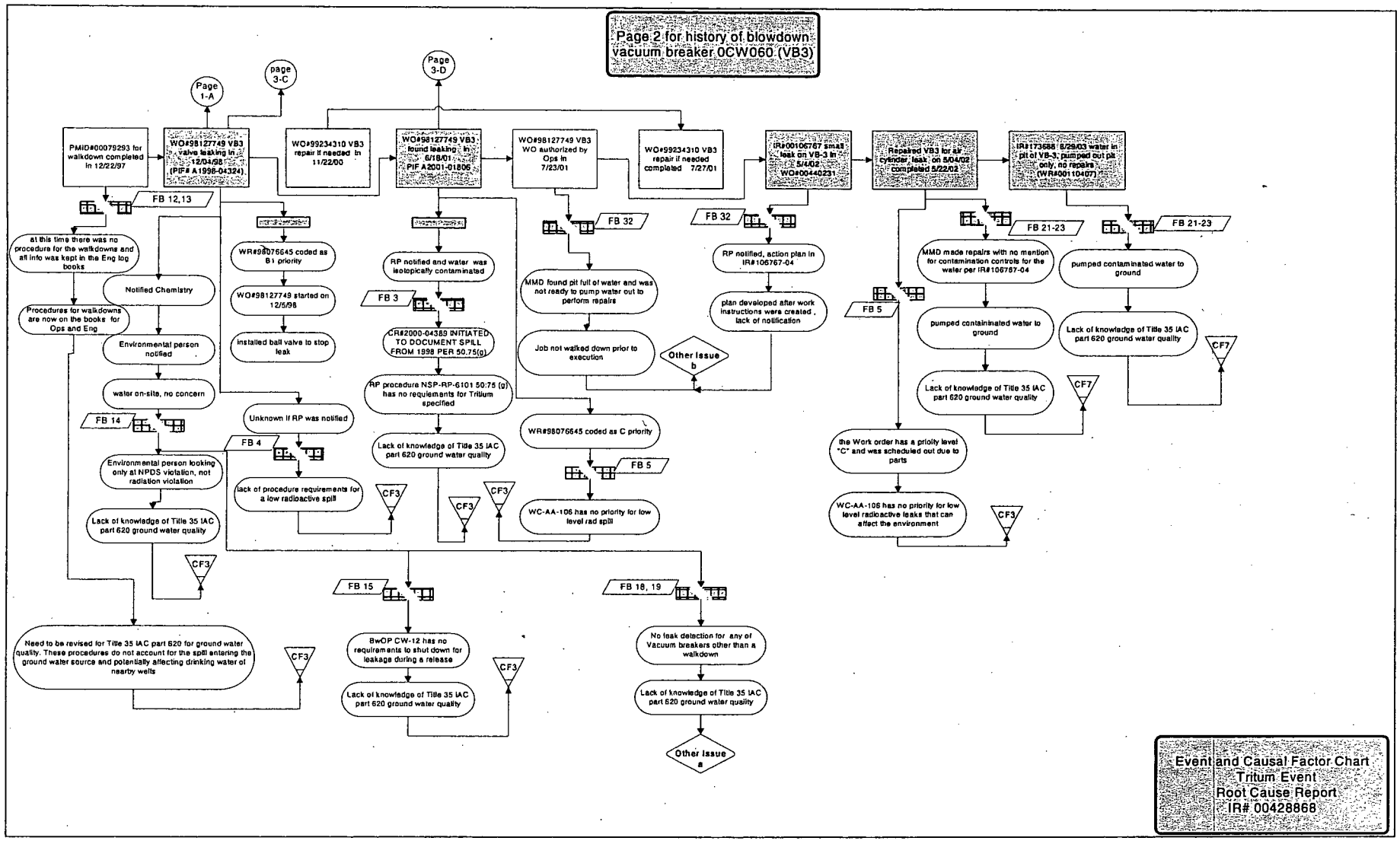
–Cause & Effect Analysis

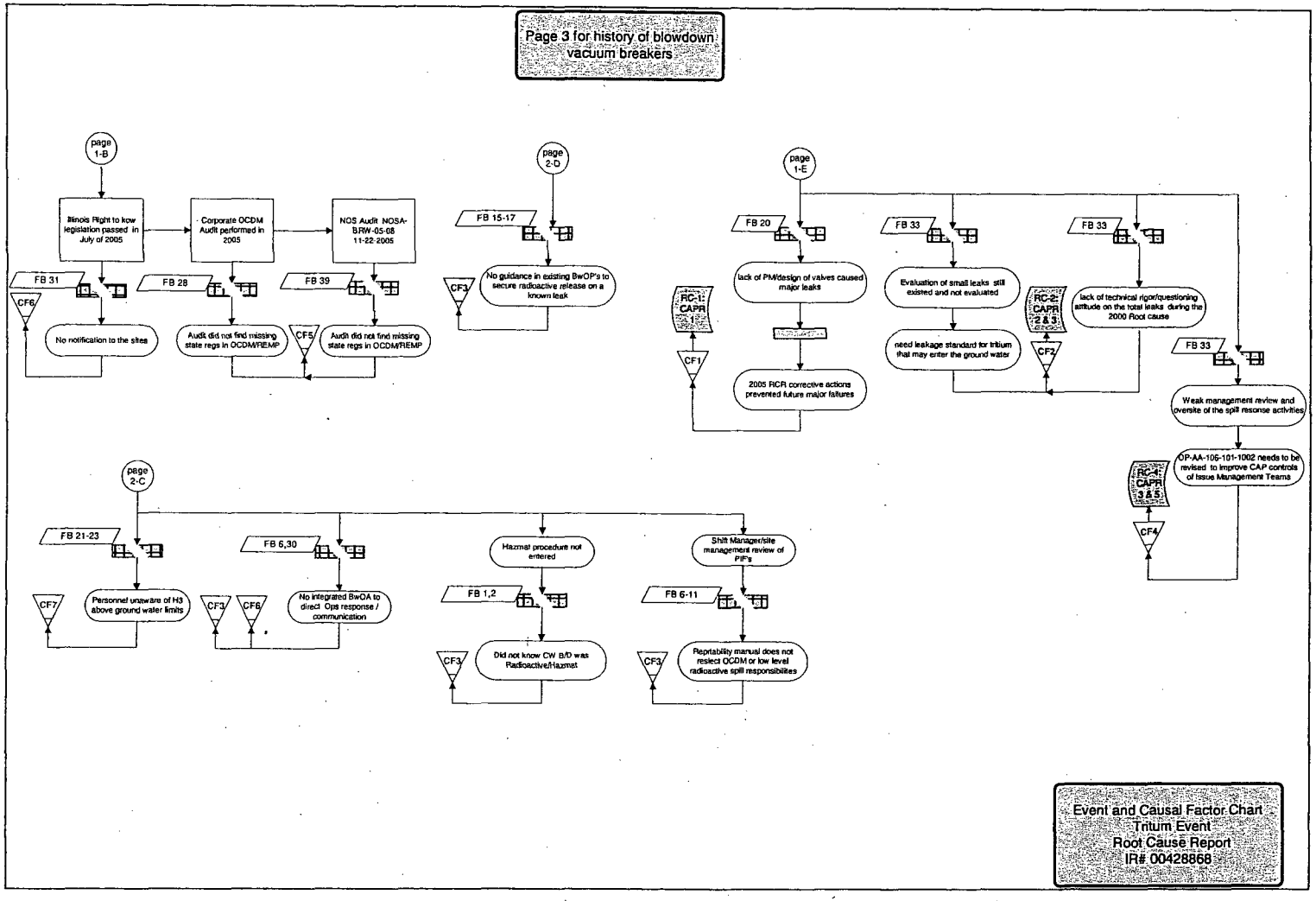
Effect / Symptom	Why	Cause / Reason
Tritium found off site		Ineffective response in 2000
Ineffective response in 2000		Sampling not performed for tritium in groundwater
Sampling not performed for tritium in groundwater		Poor decision by Spill Team not to sample
Poor decision by Spill Team not to sample		Weak questioning attitude and inadequate challenge culture (Root Cause 4)
Weak questioning attitude and inadequate challenge culture		OP-AA-106-101-1002 (currently, OP-AA-101-503 in year 2000) was not specific enough in regarding management reporting requirements (CAPR 5)

Attachment 4

E&CF Chart




Page 2 for history of blowdown vacuum breaker 0CW060 (VB3)
Page 1-A
page 3-C
Page 3-D
PMID#00079293 for walkdown completed in 12/22/97
WO#98127749 VB3 valve leaking in 12/04/98 (PIF# A1998-04324)
WO#99234310 VB3 repair if needed in 11/22/00
WO#98127749 VB3 found leaking in 6/18/01 PIF A2001-01806
WO#98127749 VB3 WO authorized by Ops in 7/23/01
WO#99234310 VB3 repair if needed completed 7/27/01
IR#00106767 small leak on VB-3 in 5/4/02 WO#00440231
Repaired VB3 for air cylinder leak on 5/04/02 completed 5/22/02
IR#173688 8/29/03 water in pit of VB-3; pumped out pit only, no repairs (WR#00110407)
FB 12,13
FB 32
FB 32
FB 21-23
FB 21-23
at this time there was no procedure for the walkdowns and all info was kept in the Eng log books
Notified Chemistry
Procedures for walkdowns are now on the books for Ops and Eng
Environmental person notified
water on-site, no concern
FB 14
Environmental person looking only at NPDS violation, not radiation violation
Lack of knowledge of Title 35 IAC part 620 ground water quality
CF3
Need to be revised for Title 35 IAC part 620 for ground water quality. These procedures do not account for the spill entering the ground water source and potentially affecting drinking water of nearby wells
WR#98076645 coded as B1 priority
WO#98127749 started on 12/5/98
installed ball valve to stop leak
Unknown if RP was notified
FB 4
lack of procedure requirements for a low radioactive spill
CF3
RP notified and water was isotopically contaminated
FB 3
CR#2000-04389 INITIATED TO DOCUMENT SPILL FROM 1998 PER 50.75(g)
RP procedure NSP-RP-6101 50.75 (g) has no requirements for Tritium specified
Lack of knowledge of Title 35 IAC part 620 ground water quality
CF3
CF3
MMD found pit full of water and was not ready to pump water out to perform repairs
Job not walked down prior to execution
Other Issue b
WR#98076645 coded as C priority
FB 5
WC-AA-106 has no priority for low level rad spill
CF3
RP notified, action plan in IR#106767-04
plan developed after work instructions were created , lack of notification
FB 5
MMD made repairs with no mention for contamination controls for the water per IR#106767-04
pumped contaminated water to ground
pumped contaminated water to ground
Lack of knowledge of Title 35 IAC part 620 ground water quality
CF7
Lack of knowledge of Title 35 IAC part 620 ground water quality
CF7
the Work order has a priority level "C" and was scheduled out due to parts
WC-AA-106 has no priority for low level radioactive leaks that can affect the environment
CF3
FB 15
BwOP CW-12 has no requirements to shut down for leakage during a release
Lack of knowledge of Title 35 IAC part 620 ground water quality
CF3
FB 18, 19
No leak detection for any of Vacuum breakers other than a walkdown
Lack of knowledge of Title 35 IAC part 620 ground water quality
Other Issue a
Event and Causal Factor Chart
Tritium Event
Root Cause Report
IR# 00428868


Page 3 for history of blowdown vacuum breakers
page 1-B
Illinois Right to know legislation passed in July of 2005
Corporate OCDM Audit performed in 2005
NOS Audit NOSA-BRW-05-08 11-22-2005
FB 31
FB 28
FB 39
CF6
No notification to the sites
Audit did not find missing state regs in OCDM/REMP
CF5
Audit did not find missing state regs in OCDM/REMP
page 2-D
FB 15-17
CF3
No guidance in existing BwOP's to secure radioactive release on a known leak
page 1-E
FB 20
FB 33
FB 33
lack of PM/design of valves caused major leaks
Evaluation of small leaks still existed and not evaluated
lack of technical rigor/questioning attitude on the total leaks during the 2000 Root cause
RC-1: CAPR 1
RC-2: CAPR 2 & 3
CF1
CF2
2005 RCR corrective actions prevented future major failures
need leakage standard for tritium that may enter the ground water
FB 33
Weak management review and oversite of the spill resonse activities
OP-AA-106-101-1002 needs to be revised to improve CAP controls of Issue Management Teams
RC-4: CAPR 3 & 5
CF4
page 2-C
FB 21-23
FB 6,30
Hazmat procedure not entered
Shift Manager/site management review of PIFs
CF7
Personnel unaware of H3 above ground water limits
CF3
CF6
No integrated BwOA to direct Ops response / communication
FB 1,2
FB 6-11
CF3
Did not know CW B/D was Radioactive/Hazmat
CF3
Reportability manual does not reflect OCDM or low level radioactive spill responsibilities
Event and Causal Factor Chart
Tritium Event
Root Cause Report
IR# 00428868

Attachment 5
Change Analysis

(The Change Analysis tool was inadequate to use effectively and was therefore not utilized as an input to this root cause report.)

Factors That Influence Performance	Interview Questions	Successful Performance	Failed Performance	Change?	Causal Factor?

Factors That Influence Performance	Interview Questions	Successful Performance	Failed Performance	Change?	Causal Factor?

Factors That Influence Performance	Interview Questions	Successful Performance	Failed Performance	Change?	Causal Factor?

Attachment 6

Circ Water Blowdown System
BACKGROUND INFORMATION

The primary function of the Circulating Water Blowdown System is to provide for lake turnover to prevent undesirable chemical buildup in the lake. The secondary function of the Circ Water Blowdown System is to provide dilution for liquid rad waste releases. (See Attachment 7 for map.)

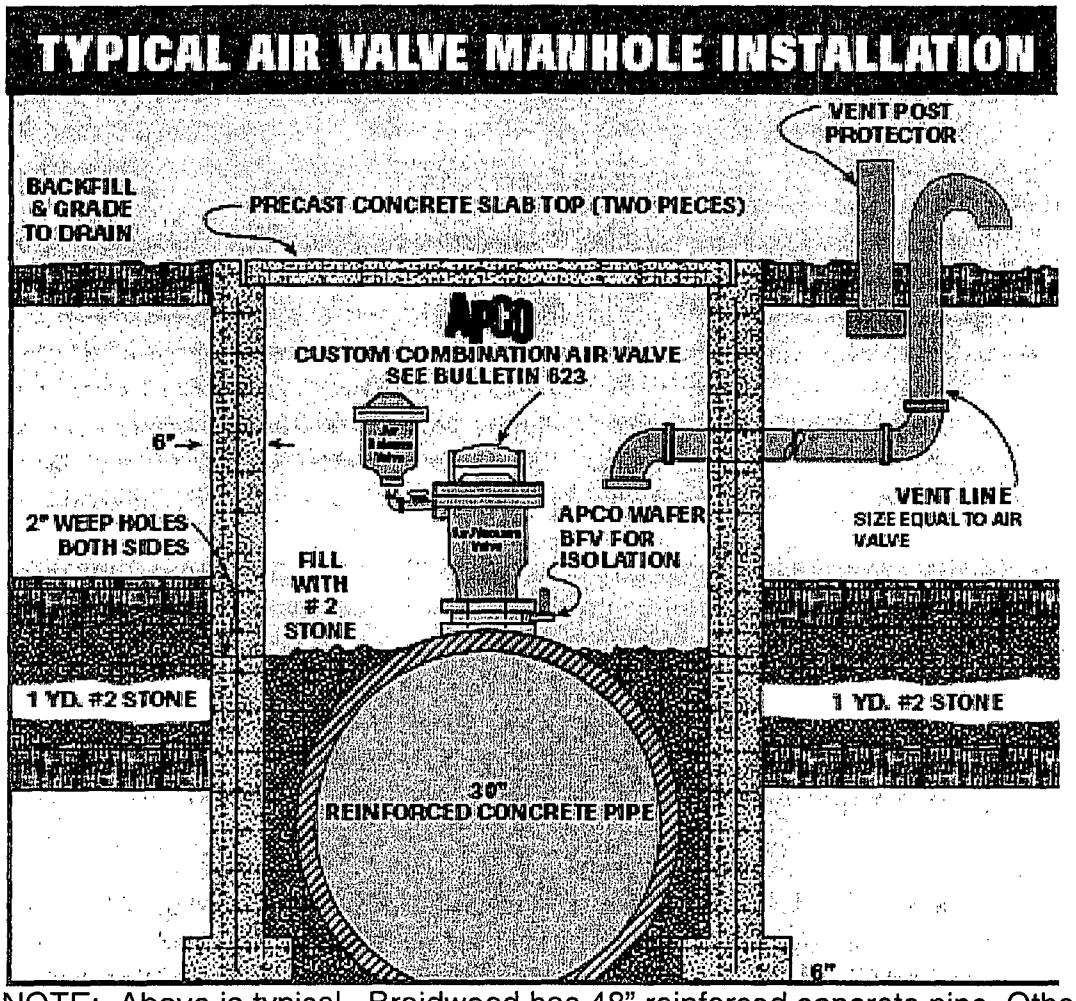
The Circulating Water Blowdown System is designed to return Cooling Lake water back to the Kankakee River. Processed fluids from the Sewage Treatment System and the Radwaste Treatment Systems discharge directly into the Circulating Water Blowdown system, where dilution occurs prior to release to the Kankakee River. The Wastewater Treatment Plant and the Demineralizer Regenerant Waste systems along with various strainer/filter backwashes are returned to the Cooling Lake and thus are indirectly returned to the Kankakee River through the Blowdown line after dilution by the Cooling Lake.

The Circ Water Blowdown system begins at the Circ Water System supply piping to the condenser. Two 24" carbon steel pipes tap off the Circulating Water supply piping (one from each unit) and combine into a 36" common header. A motor operated isolation valve (1/2CW018) is provided on each 24" line. The 6" Radwaste Treatment System discharge pipe connects to the 36" blowdown header. Downstream of the radwaste connection, the blowdown pipe is expanded to 48" prior to connection to the 3" Sewage Treatment Plant discharge pipe.

The 48" diameter blowdown pipe is reinforced concrete pipe (RCP) and runs along owner-controlled property until reaching the Blowdown structure at the Kankakee River. Eleven vacuum breaker assemblies are incorporated at the high points along the 48" diameter RCP to prevent pipe implosion when the blowdown system is shut off. The 48" RCP is split and reduced to two 24" discharge pipes at the Kankakee River blowdown structure. Each 24" discharge pipe was originally equipped with a motor operated spray valve. The entire piping network is approximately 29,000 ft long and was originally operated at about 12,000 gpm (~2.5 ft/s).

The Circ Water Blowdown system was originally designed to be maintained full of water and pressurized. This was accomplished through manipulation of the Blowdown Spray Valves, at the Kankakee River blowdown structure. These valves were susceptible to freezing due to their location and system operation requirements. Based on this, other maintenance issues, and parts obsolescence, these valves were eventually abandoned in the full open position in the late

1980's. To allow air release from the piping on start-up and to allow air introduction to protect against vacuum damage to the piping, vacuum breakers are installed.



NOTE: Above is typical. Braidwood has 48" reinforced concrete pipe. Other differences may apply.

System control was transferred to the upstream motor operator isolation valves located in the turbine building. This modification caused the blowdown line to operate in a partially voided condition in various locations, depending on elevation which allowed column separation water hammer events to occur when flow rates were changed significantly, i.e.; during system start-up or shut down. Events were not initially seen because blowdown was essentially in service all the time. As a result of this change in operational methodology, the blowdown system would no longer be maintained full and pressurized upon shutdown. Minimal technical review was performed on the hydraulic transient effects on the vacuum breakers from this method of operation.

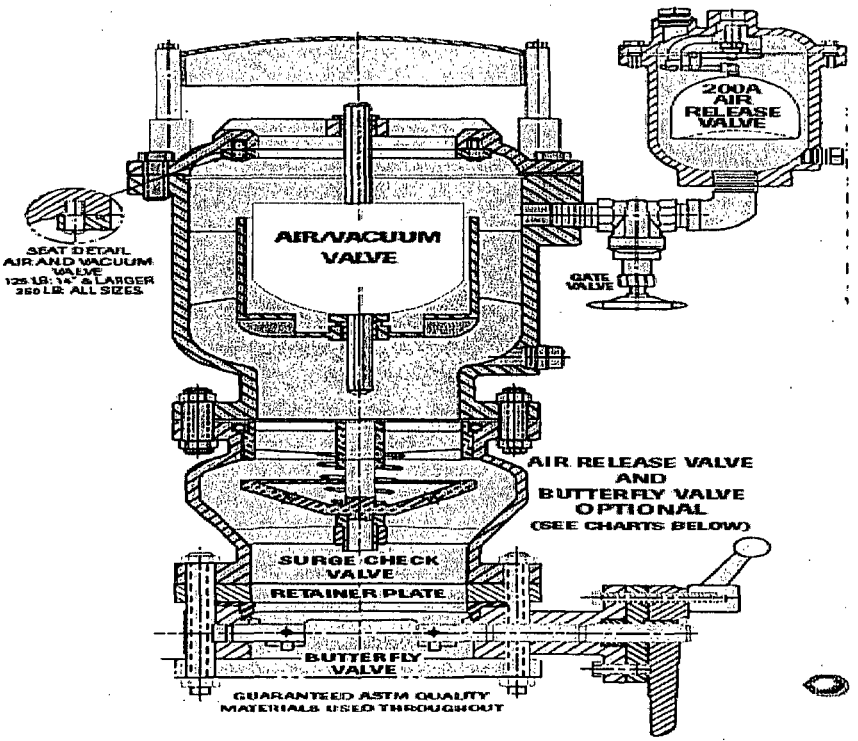
A more rigorous technical review may have initiated the installation of surge protected check valves (which eventually occurred in 2001) before the majority of the leaks described in this report occurred. This is a missed opportunity.

In 1997, the Chemical Feed System was relocated from the Turbine Building to the Lake Screen House under modification M20-0-95-003. One of the primary reasons for centralization of the Chemical Feed system to the Lake Screen House was to reduce maintenance cost. This design change necessitated isolating the Circ Water Blowdown System on a daily basis to accommodate biocide injections into the Circ Water System, because our permits do not authorize discharge of biocide to the Kankakee River. When both units were in operation this was not an issue because partial blowdown flow was maintained from the unit not being chlorinated. The problem became apparent during outages when one unit was shut down. In this configuration, blowdown flow was stopped and started whenever the operating unit was chlorinated.

The daily requirement to isolate Circulating Water Blowdown for biocide injection, prompted the Operations Department to challenge the BwOP CW-12 procedural requirement to slowly open the motor operated valves for system start-up. BwOP CW-12 was revised to allow fast motorized operation of motor operated valves, in lieu of slower manual throttling following short periods of system shutdown (i.e.: biocide injections).

Attachment 6

Typical vacuum breaker:



Work history on the Circulating Water Blowdown System vacuum breakers was reviewed. There were no recorded vacuum breaker float assembly failures prior to 2000, however several instances of leaking air release valves were noted from the review. The VB-3 air release valve was discovered leaking in 12/98. PIF # A1998-04324 was generated to address the flooding of site property and the Smiley Road ditch immediately adjacent to site property. The piping to the air release valve on the VB-1 failed in 12/96. The complete vacuum breaker assembly including air release valve was replaced with a new assembly in 1997. It should be noted that the VB-1 vacuum breaker failed again on 11/20/2000. The float assembly broke at the bowl to guide bar weld. No other significant work history was identified.

The failure of the VB-2 float assembly was discussed with the vendor. Based on the failure description, the vendor indicated that it appeared to be consistent with the effects of a pressure surge (i.e. water hammer). The vendor indicated that surge protection check valves should be considered for a vacuum breaker when pipe flows exceed 6 ft/s and are required when flow velocities exceed 10 ft/s. The vendor also recommended a 7-10 year PM frequency to address valve elastomer degradation. The condition was addressed by revising the operating procedure BwOP CW-12 to manually open and close the valves to slowly initiate or terminate blowdown flow.

Attachment 6

The present circulating water blowdown system operates as follows. On system startup, the air/vacuum valve exhausts large amounts of air from the piping system until the float assembly in the air/vacuum valve rises with water level to close and seal during normal system operation. To prevent the inrushing water from causing damage to the air/vacuum valve float, a surge check valve is installed just underneath the air/vacuum valve. The surge check is a spring loaded, normally open valve, which passes air through unrestricted. When water rushes into the check valve, the disc begins to close against the spring tension and reduces the flow rate of water into the air/vacuum valve by means of throttling holes in the disc. This ensures gentle closing of the air/vacuum valve float, regardless of initial flow velocity into the valve and minimizes pressure surges. Upon system shutdown, the vacuum valve is designed to open as water level decreases. The air release valve provides two functions. The primary function is to release small amounts of entrained air that accumulates at the high points during normal system operation. If not removed, this air that would increase head loss and reduce process flow. The air release valve also facilitates earlier opening of the main air/vacuum valve on system shutdown. On shutdowns, air pockets that develop at high points may be at positive pressure, tending to hold the main air/vacuum float on its seat even though water level is below the float assembly. However, the air release valve will vent the air and allow the main air/vacuum valve to open as soon as water level drops. Each vacuum breaker is provided with a butterfly isolation valve to facilitate vacuum breaker maintenance.

Modification of 2001-2003 changed the design of the air / vacuum valve assembly to a slow closing design with the use of a surge protector valve in-line. This modification protects the air/vacuum valves from pressure surges experienced during water hammer events.

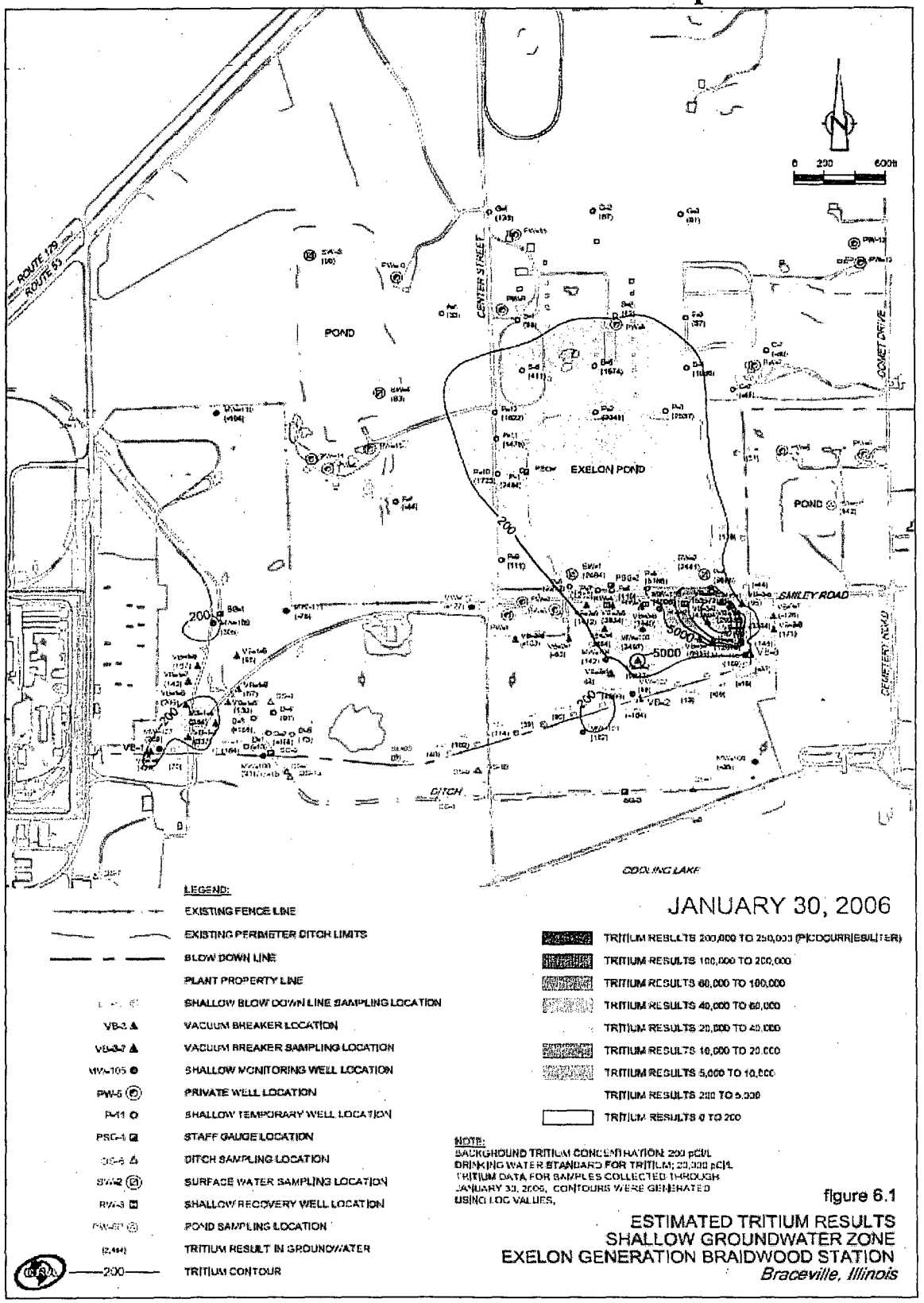
Modification of 2003 installed CW Blowdown Booster Pumps to increase the blowdown flow rate to 25,000 gpm for improving lake chemistry. With increased flow rates during booster pump operation the volume of voided blowdown line may decrease, closing previously open air / vacuum valves under lower flow conditions. Start up and shut down procedures for the booster pumps specify flow / pump increase / decrease ramp rates to minimize potential column separation water hammer pressure surges.

Attachment 6

Modification of 2005 installed a de-chlorination modification to allow continuous operation of the Blowdown System while performing unit chlorination. This modification allowed blowdown to be in-service essentially all the time, reducing the potential for air / vacuum valves leaks caused by system flow rate changes.

The aggregate impact of the three modifications was to assure nearly continuous operation of the blowdown system which minimizes the inclusion of air and the possibility of damaging water hammer at the vacuum breaker valves.

Attachment 7 Tritium Plume Maps



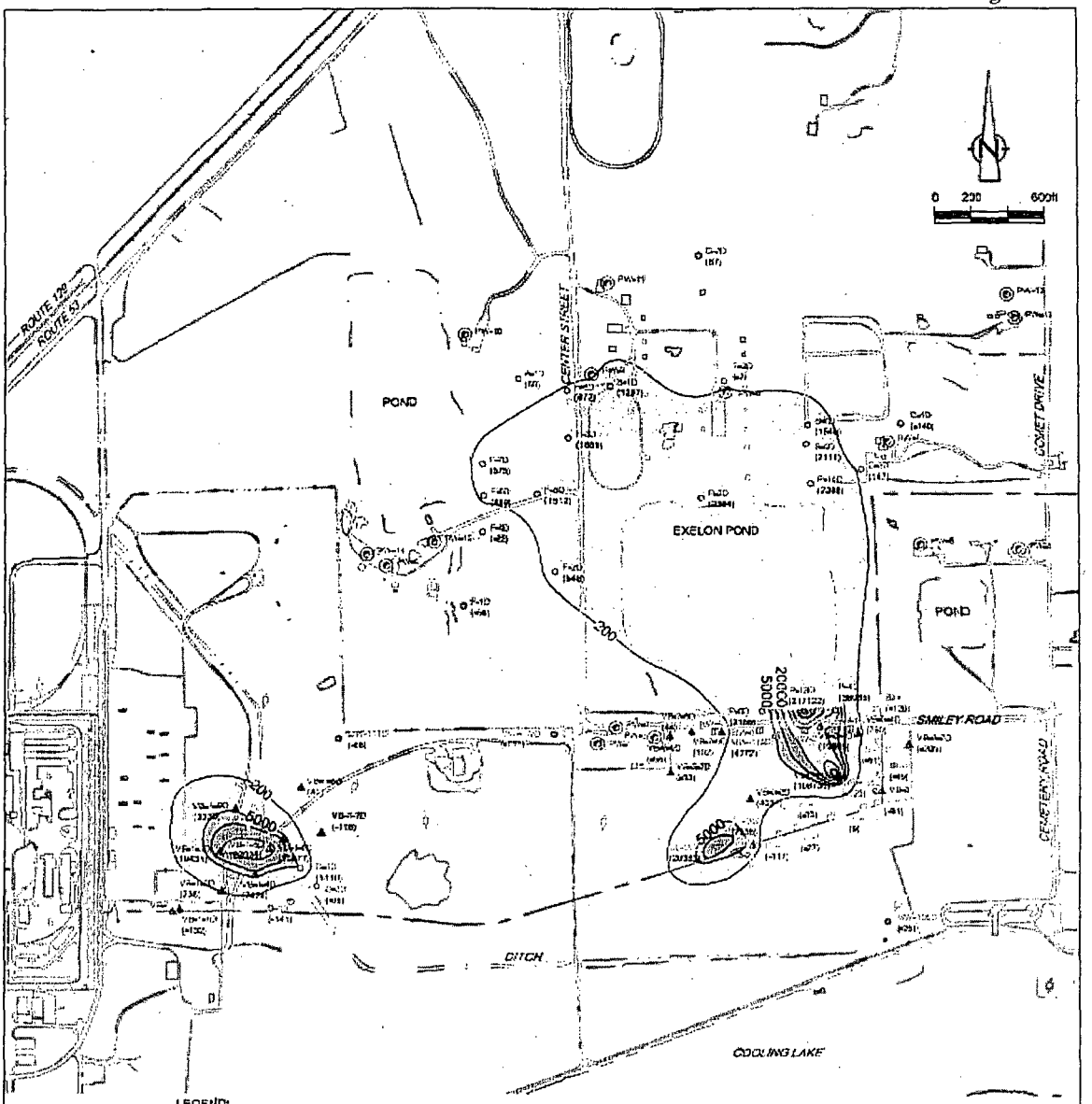


figure 6.2

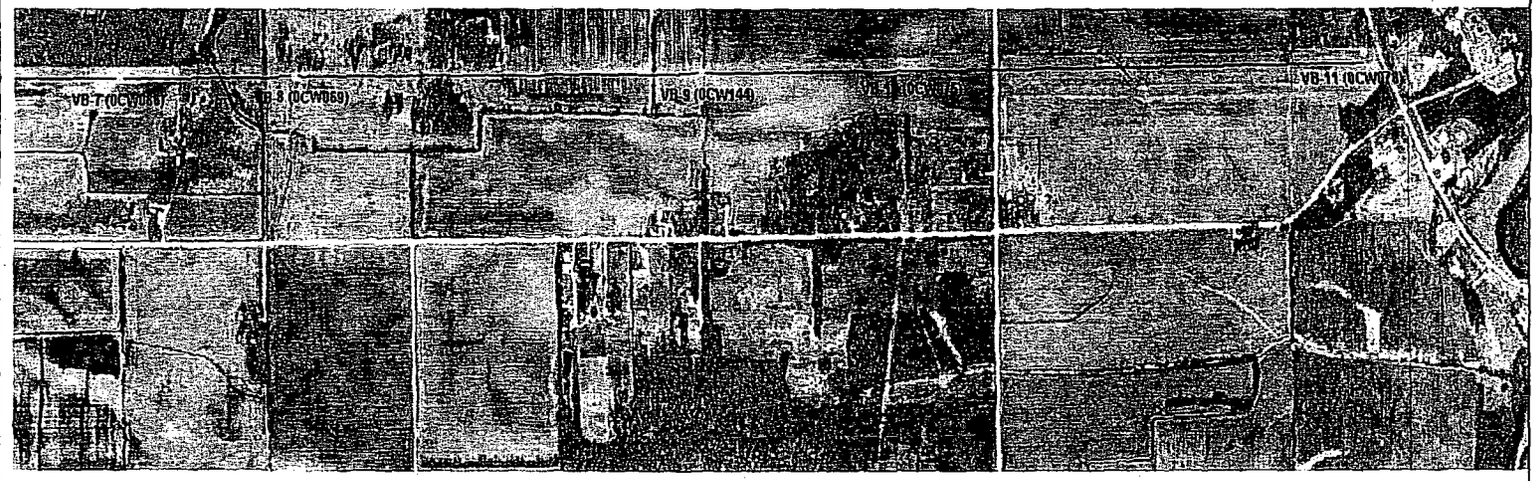
ESTIMATED TRITIUM RESULTS
DEEP GROUNDWATER ZONE
EXELON GENERATION BRAIDWOOD STATION
Braceville, Illinois

North

Godley Illinois

Braidwood Station →

→ Ω



→ Ω

Kankakee River

Attachment 8

Review of Exelon Hazmat Spill Response Procedures

Page 1 of 3

In general, there is no spill response procedure, which would acknowledge the subsurface water transport mechanism from onsite to offsite locations. The three documents reviewed were a draft procedure circulated in 10/16/90, "General Action Plan for Response to Unmonitored Releases and Very Low Level Radioactive Spills", BwAP 750-4, "Hazardous Material Spill Response", and BwAP 1100-16, "Fire/Hazardous Materials Spill and/or Injury Response", and NSP-RP-6101, "10 CFR 50.75(g)(1) Documentation Requirements".

The most significant barrier deficiencies noted was that the 1990 draft procedure may have prompted reviewing hydrology and dose to the public from radiological contamination of groundwater. Additionally, the procedure to document the spill for 10 CFR 50.75(g)(1) requirements for decommissioning prompts to perform a potential dose impact to the public from the spill, but does not require any specific pathway (i.e. subsurface migration of contaminants to drinking water).

Procedure	Relevant Content	Barrier Analysis
Draft Procedure CSG-001, "General Action Plan for Response to Unmonitored Releases and Very Low Level Radioactive Spills" Circulated as a Draft procedure 10/16/90. No record of this becoming an actual procedure. This procedure contains information relevant to the underground water dose pathway to the public now being evaluated. Not implementing this procedure was a missed opportunity to erect a barrier to recognize	The draft procedure contained pertinent information about: • For situations involving subsurface contamination, corrective action may mean the preparation of a submittal pursuant to the Il Adm. Code 340.3020 and 10 CFR 20.302 requesting the in-place disposal of subsurface contamination. • Environment – refers to any surface water, groundwater, sanitary or storm sewers, soil, land surface, or subsurface strata and vegetation. • Subsurface contamination and hydrology concerns • Reviewing to ensure the spill is not in excess of Reportable Quantity quantities in 40 CFR 302 App B or 40 CFR 355 App A • Required evaluation of exposure pathways from infiltration and contamination of groundwater.	Missed opportunity to erect a barrier. This procedure may have prompted recognition of dose impacts from the contamination of groundwater and supporting hydrology issues. May have provided an opportunity for all former ComEd nuclear plants to recognize the potential issue.
		Page 2 of 3
BwAP 750-4, "Hazardous Material Spill Response"	In general, site personnel would not consider entry into the hazmat spill procedure for a water spill. The procedure contains the following pertinent information: • The procedure references Hazardous Materials as listed in 40 CFR 302.4, which lists many chemicals, but not	Minor missed barrier. Missing this barrier was of no consequence. The RP organization did not

Procedure	Relevant Content	Barrier Analysis
	radioactive material. The intent of this reference is to ensure that a "Reportable Quantity" has not been spilled on the ground. The absence of radioactive materials from the list in the procedure does not preclude someone from looking for radioactive material in 40 CFR 302.4, but the procedure does not offer a clear barrier to trip recognition of a radioactive material spill as a hazmat event per this procedure. Even if radioactive materials was clearly on the Reportable Quantity list, the RP organization does not have a procedure documenting additional required actions. • The procedure states, "Spills containing radiologically contaminated material shall be reported to the Radiation Protection Dept.	have subsequent procedures to respond to the subsurface transport issues, which are of issue today.
BwAP 1100-16, "Fire/Hazardous Materials Spill and/or Injury Response"	The hazmat procedure does not contain information to specify actions that might direct specific radiological actions to minimize the significance of a similar event. The procedure essentially defers radiological spills to the RP organization. The procedure contains the following radiological information: • Notify Rad Protection to dispatch personnel to the fire/spill area for radiation detection and first aid purposes.	Minor missed barrier. Missing this barrier was of no consequence. The RP organization did not have subsequent procedures to respond to the subsurface transport issues, which are of issue today.
NSP-RP-6101, "10 CFR 50.75(g)(1) Documentation Requirements"	This procedure is intended to provide the following information as required from the regulation: • 10 CFR 50.75(g)(1) Records of spills or other unusual occurrences involving the spread of contamination in and around the facility, equipment, or site. These records may be limited to instances when significant contamination remains after any cleanup procedures or when there is reasonable likelihood that contaminants may have spread to inaccessible areas as in the case of possible seepage into porous materials such as concrete. These records must include any known information on identification of involved nuclides, quantities, forms, and concentrations. • The actual procedure requires addressing: o Concentrations of involved radionuclides o Quantities of material(s) o Forms of material(s), (e.g. solubility and permeability of the contaminant) o Description of the event o Impact of the remaining radioactive material on the health and safety of the public o Affected areas • The procedure prompts to perform a potential dose impact to members of the public, but it does not describe pathways to be analyzed (i.e. subsurface migration of contaminants to drinking water). The general absence of tools to calculate the specifics of subsurface transport mechanisms may have prompted actual measurements through the drilling of wells to sample water or sample existing offsite wells. Corrective Action (CA-21) addresses performing a dose assessment to determine the dose impact to the public from radiological spills by including this action in the 10 CFR 50.75(g)(1) procedure. The purpose of corrective action 21 is to link	**Page 3 of 3** Missed barrier The procedure requires an assessment of potential dose to the public from the remaining radioactive material, but does not prompt for the pathway of subsurface migration through groundwater to drinking water.

Procedure	Relevant Content	Barrier Analysis
	the 10CFR 50.75(g) with the ODCM for tracking the impact on dose of isotopics in groundwater.	

Attachment 9

Reportability Manual Review - LS-AA-1020 and LS-AA-1110

Various documents were reviewed by this Root Cause Investigation Team to determine the expected reporting requirements for an event such as discovering radiologically contaminated water leaking from a plant system onto the ground within the owner-controlled area.

LS-AA-1020 Radiological Decision Tree was reviewed. The Liquid Release or Spill portion of the tree references SAF 1.9, News Release or Notification of Other Government Agency. SAF 1.9 requires NRC notification for any event related to the health and safety of the public or onsite personnel, or protection of the environment requiring a news release or notification of another government agency. One example described is the unplanned release of radioactively contaminated materials. Since the vacuum breaker leaks (spills) were contained onsite, the leak would not be characterized as a release per the Offsite Dose Calculation Manual.

Since the leak was onsite, there was no perceived health or safety risk to the public. A review of several Incident Reports (IR's) indicates that these leaks were not considered a public risk since the leaks were onsite. These IR's also reasonably concluded that National Pollution Discharge Elimination System (NPDES) violations did not occur and therefore, Environmental Protection Agency (EPA) notification was not required. Based on the nature of the leak, there was no safety or health risk to onsite personnel. Therefore, it was reasonable to conclude that these events were not reportable per SAF 1.9.

The Liquid Release or Spill portion of the Radiological Decision Tree also references RAD 1.1, Events Involving Byproduct, Source or Special Nuclear Material that Cause or Threaten to Cause Significant Exposure or Release. One of the reporting requirements concerns the release of radioactive material inside or outside the restricted area, but is not reportable if the location is not normally stationed during routine operations. Since personnel would not normally be stationed at the vacuum breakers, reporting was not required.

RAD 1.4, Liquid Effluent Release requires reporting when radioactive material is present at levels greater than 10 times applicable limits. The piping leaks were within the restricted areas and therefore were not considered an effluent release. Migration of contaminated groundwater offsite should be considered an effluent release, but was not considered. To date, measurable tritium concentrations in groundwater offsite are within 10 times the applicable limits. The event is not reportable per RAD 1.4.

RAD 1.8, Effluent Release was not considered applicable since a release normally occurs at the authorized or intended discharge point. Therefore, reportability per RAD 1.8 was not considered. Offsite release via groundwater was not considered. Based on the measured tritium results off site, the requirements described in RAD 1.8 have not been exceeded and therefore, reportability per RAD 1.8 is not required.

RAD 1.21, Release of Radionuclides, requires reporting when the limits of 40 CFR 302 are exceeded. For tritium, the 40 CFR 302 limit is 100 Curies released within a 24-hour period. Review of effluent release data indicates that the 100-curie limit was not challenged during radioactive releases over the vacuum breaker leakage timeframe. Therefore, reportability per RAD 1.21 was not required.

RAD 1.22, Release of Hazardous Substances (including radionuclides) is not applicable based on the RAD 1.21 discussion.

The other sections of the Liquid Release or Spill portion of the Radiological Decision Tree do not apply.

The other sections of the Radiological Decision Tree were reviewed and do not apply.

LS-AA-1020 Environmental decision tree was also reviewed. The Other Significant Event section was reviewed. ENV 3.26 Unusual or Important Environmental Events requires reporting of any event that did or could have significant environmental impact. It is reasonable that a blowdown water spill onsite would not have a significant environmental impact and therefore notification would not be made. However, potential groundwater contamination and migration to public wells was not considered.

The other sections of the Environmental Decision Tree were reviewed and would not apply.

40 CFR 141.16 states that the average annual tritium concentration shall not exceed 20,000 pCi/L in a community drinking water system. A community drinking water system is defined in the regulation as a public water system that serves at least 15 year round residents. The reportability manual appropriately references 40 CFR 141.

35 IAC 620 has the same 20,000 pCi/L limit and definition of community drinking water system as described in 40 CFR 141.16. However, 35 IAC 620 does not limit the tritium concentration to community drinking water. This Illinois standard limits tritium concentration in "Class I: Potable Resource Water," which is defined, in part, as water located 10 feet or more below the surface that is capable of potable use. Per discussion with Conestoga-Rovers & Associates and the Exelon Hydrologist, onsite groundwater at Braidwood station is classified as Class I: Potable Resource Water in accordance with 35 IAC 620. Therefore, any tritium leakage into the groundwater onsite could exceed the requirements of 35 IAC 620.

The reporting requirements for the Radiological Environmental Monitoring Program (REMP) are specified in the Braidwood ODCM, section 12.5.1. Table 12.5-2 lists REMP reporting levels for tritium and other radionuclides that are monitored in various types of samples obtained. These ODCM required reporting requirements are not listed in the Reportability Manual. Groundwater samples indicate that the reporting level of tritium per Table 12.5-2 have been exceeded.

The Braidwood ODCM REMP drinking water tritium concentration reporting requirements are consistent with the requirements of 40 CFR 141 and 35 IAC 620. However, per ODCM Section 12.5.1, reportability is based on a quarterly average. 40 CFR 141 and 35 IAC 620 reportability are based on an annual average – the ODCM reportability is conservative and consistent with the recommendations in NUREG 1301 Section 3.12.1.

There is no mention of 35 IAC 611 or 35 IAC 620 requirements in the Braidwood ODCM (CA4).

The Reportability Manual was reviewed for references to the various drinking water and groundwater standards. There is appropriate reference to 40 CFR 141 and 35 IAC 611. However, there were not sufficient references to 35 IAC 620. Based on this review, there was inadequate knowledge of the requirements of 35 IAC 620 and the transport of radioactivity offsite via the groundwater pathway.

In 2005, Illinois passed SB241, which became effective on July 25, 2005. This legislation states that if the Illinois Environmental Protection Agency (IEPA) makes a determination that groundwater poses a threat of exposure above Class I groundwater standards (35 IAC 620), then public notification is required. The IEPA does not require conclusive evidence of exceeding a standard. The notification can be based on modeling that demonstrates a trend towards exceeding a standard.

While this legislation does not require site reporting and does not change daily operation, it does impact the site because public notification can be made based on groundwater contaminant concentrations that are below reportable thresholds. There is no mechanism in place for site technical expertise to be made aware of new legislation such as Illinois SB241 (CA8).

References

Braidwood Offsite Dose Calculation Manual
LS-AA-1020, Reportability Reference Manual, Revision 8
LS-AA-1110, Reportable Event SAF, Revision 6
LS-AA-1120, Reportable Event Radiation (RAD), Revision 3
LS-MW-1310, Reportable Event SAF, Revision 3
LS-MW-1340, Reportable Event, ENV, Revision 4
LS-AA-1400, Event Reporting Guidelines, Revision 2
LS-MW-1340, Reportable Events, ENV, Revision 4
40 CFR 302, Designation, Reportable Quantities, and Notification
40 CFR 141, National Primary Drinking Water Regulations
35 IAC 611, Primary Drinking Water Standards
35 IAC 620, Groundwater Quality

Attachment 10

Summary of Applicable State, Federal, and Offsite Dose Calculation Manual (ODCM) Regulations and Requirements for Tritium Releases to the Environment

TITLE 35: ENVIRONMENTAL PROTECTION
SUBTITLE F: PUBLIC WATER SUPPLIES
CHAPTER I: POLLUTION CONTROL BOARD
PART 620.410

GROUNDWATER QUALITY

Effective November 25, 1991Class I: Potable Groundwater

e) Beta Particle and Photon Radioactivity

1) Except due to natural causes, the average annual concentration of beta particle and photon radioactivity from man-made radionuclides shall not exceed a dose equivalent to the total body organ greater than 4 mrem/year in Class I groundwater. If two or more radionuclides are present, the sum of their dose equivalent to the total body, or to any internal organ shall not exceed 4 mrem/year in Class I groundwater except due to natural causes.

2) Except for the radionuclides listed in subsection (e)(3), the concentration of man-made radionuclides causing 4 mrem total body or organ dose equivalent must be calculated on the basis of a 2 liter per day drinking water intake using the 168-hour data in accordance with the procedure set forth in NCRP Report Number 22, incorporated by reference in Section 620.125(a).

3) Except due to natural causes, the average annual concentration assumed to produce a total body or organ dose of 4 mrem/year of the following chemical constituents shall not be exceeded in Class I groundwater:

Constituent	Critical Organ	Standard (pCi/L)
Tritium	Total body	20,000.0
Strontium-90	Bone marrow	8.0

A.2.2 Liquid Effluent Concentrations Requirement

Requirement
One method of demonstrating compliance to the requirements of 10 CFR 20.1301 is to demonstrate that the annual average concentrations of radioactive material released in gaseous and liquid effluents do not exceed the values specified in 10 CFR 20 Appendix B, Table 2, Column 2. (See 10 CFR 20.1302(b)(2).) However, as noted in Section A.5.1, this mode of 10 CFR 20.1301 compliance has not been elected.

[Mode of compliance selected is as follows:]

As a means of assuring that annual concentration limits will not be exceeded, and as a matter of policy assuring that doses by the liquid pathway will be ALARA; RETS provides the following restriction:

"The concentration of radioactive material released in liquid effluents to unrestricted areas shall be limited to ten times the concentration values in Appendix B, Table 2, Column 2 to 10 CFR 20.1001-20.2402."

This also meets the requirement of Station Technical Specifications and RETS.

A.2.4 Tank Overflow

Requirement
To limit the consequences of tank overflow, the RETS/Technical Specifications may limit the quantity of radioactivity that may be stored in unprotected outdoor tanks. Unprotected tanks are tanks that are not surrounded by liners, dikes, or walls capable of holding the tank contents and that do not have tank overflows and surrounding area drains connected to the liquid radwaste treatment system. The specific objective is to provide assurance that in the event of an uncontrolled release of a tank's contents, the resulting radioactivity concentrations beyond the unrestricted area boundary, at the nearest potable water supply and at the nearest surface water supply, will be less than the limits of 10 CFR 20 Appendix B, Table 2; Column 2.

The Technical Specifications and RETS may contain a somewhat similar provision. For most nuclear power stations, specific numerical limits are specified on the number of curies allowed in affected tanks.

A.2.5 Operability and Use of the Liquid Radwaste Treatment System

Requirement
The design objectives of 10 CFR 50, Appendix I and RETS/Technical Specifications require that the liquid radwaste treatment system be operable and that appropriate portions be used to reduce releases of radioactivity when projected doses due to the liquid effluent from each reactor unit to restricted area boundaries exceed either of the following (see Section 12.3 of each station's RETS or Technical Specifications);

- 0.06 mrem to the total body in a 31 day period.
- 0.2 mrem to any organ in a 31 day period.

A.2.6 Drinking Water
Five nuclear power stations (Braidwood, Dresden, LaSalle, Quad Cities, and Zion) have requirements for calculation of drinking water dose that are related to 40 CFR 141, the Environmental Protection Agency National Primary Drinking Water Regulations. These are discussed in Section A.6.

A.6 DOSE DUE TO DRINKING WATER (40 CFR 141)
The National Primary Drinking Water Regulations, 40 CFR 141, contain the requirements of the Environmental Protection Agency applicable to public water systems. Included are limits on radioactivity concentration. Although these regulations are directed at the owners and operators of public water systems, several stations have requirements in their Technical Specifications related to 40 CFR 141.

A.6.1 40 CFR 141 Restrictions on Manmade Radionuclides
Section 141.16 states the following (not verbatim):

(a) The average annual concentration of beta particle and photon radioactivity from man-made radionuclides in drinking water shall not produce an annual dose equivalent to the total body or any internal organ greater than 4 millirem/year.

(b) Except for the radionuclides listed in Table A-0, the concentration of man-made radionuclides causing 4 mrem total body or organ dose equivalents shall be calculated on the basis of drinking 2 liter of water per day. (Using the 168 hour data listed in "Maximum Permissible Body Burdens and Maximum Permissible Concentration of Radionuclides in Air or Water for Occupational Exposure, "NBS Handbook 69 as amended August 1963, U.S. Department of Commerce.). If two or more radionuclides are present, the sum of their annual dose equivalents to the total body or any organ shall not exceed 4 millirem/year.

TABLE A-0
AVERAGE ANNUAL CONCENTRATIONS ASSUMED TO
PRODUCE A TOTAL BODY OR ORGAN DOSE OF 4 MREM/YR

Radionuclide	Critical Organ	pCi / liter
Tritium	Total body	20,000
Strontium-90	Bone marrow	8

LIQUID EFFLUENTS

Chapter 12
Revision 7
September, 2002

12.3.1 Concentration
Operability Requirements

12.3.1.A The concentration of radioactive material released in liquid effluents to UNRESTRICTED AREAS (see Braidwood Station ODCM Annex, Appendix F, Figure F-1) shall be limited to 10 times the concentration values in Appendix B, Table 2, Column 2 to 10 CFR 20.1001-20.2402, for radionuclides other than dissolved or entrained noble gases. For dissolved or entrained noble gases, the concentration shall be limited to $2x10^{-4}$ microCurie/ml total activity.

Applicability: At all times

Action:
1. With the concentration of radioactive material released in liquid effluents to UNRESTRICTED AREAS exceeding the above limits, immediately restore the concentration to within the above limits.

Surveillance Requirements

12.3.1.B.1 Radioactive liquid wastes shall be sampled and analyzed according to the sampling and analysis program of Table 12.3-1.

12.3.1.B.2 The results of the radioactivity analysis shall be used in accordance with the methodology and parameters in the ODCM to assure that the concentrations at the point of release are maintained within the limits of 12.3.1.A.

Bases
12.3.1.C

This section is provided to ensure that the concentration of radioactive materials released in liquid waste effluents to UNRESTRICTED AREAS will be less than 10 times the concentration values in Appendix B, Table 2, Column 2 to 10 CFR 20.1001-20.2402. This limitation provides additional assurance that the levels of radioactive materials in bodies of water in UNRESTRICTED AREAS will result in exposures within: (1) the Section II.A design objectives of Appendix I, 10 CFR 50, to a MEMBER OF THE PUBLIC, and (2) the limits of 10 CFR 20.1301.

This section applies to the release of radioactive materials in liquid effluents from all units at the site.

The required detection capabilities for radioactive materials in liquid waste samples are tabulated in terms of the lower limits of detection (LLDs). Detailed discussion of the LLD, and other detection limits can be found in HASL Procedures Manual, HASL-300 (revised annually), Currie, L.A., "Limits for Qualitative Detection and Quantitative Determination - Application to Radiochemistry," Anal. Chem. 40, 586-93 (1968), and Hartwell, J.K., "Detection Limits for Radioanalytical Counting Techniques," Atlantic Richfield Hanford Company Report ARH-SA-215 (June 1975).

TABLE 12.3-1

RADIOACTIVE LIQUID WASTE SAMPLING AND ANALYSIS PROGRAM

LIQUID RELEASE TYPE	SAMPLING FREQUENCY	MINIMUM ANALYSIS FREQUENCY	TYPE OF ACTIVITY ANALYSIS	LOWER LIMIT OF DETECTION (LLD)[1] (μCi/ml)
1. Batch Release Tanks[2]	P Each Batch	P Each Batch	Principal Gamma Emitters[7]	$5x10^{-7}$
			I-131	$1x10^{-6}$
	P One Batch/M	M	Dissolved and Entrained Gases (Gamma Emitters)	$1x10^{-5}$
	P Each Batch	M Composite [3]	H-3	$1x10^{-5}$
	P Each Batch	Q Composite [3]	Gross Alpha	$1x10^{-7}$
			Sr-89, Sr-90	$5x10^{-8}$
			Fe-55	$1x10^{-6}$
2. Continuous Releases [4]	Continuous[5]	W Composite[5]	Principal Gamma Emitters[7]	$5x10^{-7}$
			I-131	$1x10^{-6}$
a. Circulating Water Blowdown	M Grab Sample	M	Dissolved and Entrained Gases (Gamma Emitters)	$1x10^{-5}$
b. Waste Water Treatment Discharge to Circulating Water Discharge	Continuous[5]	M Composite[5]	H-3	$1x10^{-5}$
			Gross Alpha	$1x10^{-7}$
c. Condensate Polisher Sump Discharge	Continuous[5]	Q Composite[5]	Sr-89, Sr-90	$5x10^{-8}$
			Fe-55	$1x10^{-6}$

TABLE 12.3-1 (Continued)

RADIOACTIVE LIQUID WASTE SAMPLING AND ANALYSIS PROGRAM

LIQUID RELEASE TYPE	SAMPLING FREQUENCY	MINIMUM ANALYSIS FREQUENCY	TYPE OF ACTIVITY ANALYSIS	LOWER LIMIT OF DETECTION (LLD)[1](μCi/ml)
3. Continuous Release[4] Essential Service Water Reactor Containment Fan Cooler (RCFC) Outlet Line	W[6] Grab Sample	W[6]	Principal Gamma Emitters[7]	$5x10^{-7}$
			I-131	$1x10^{-6}$
			H-3	$1x10^{-5}$
		M[6]	Dissolved and Entrained Gases (Gamma Emitters)	$1x10^{-5}$
4. Continuous Surge Tank Vent-Component Cooling Water Line[8]	None	None	Principal Gamma Emitters[7]	$5x10^{-7}$
			Dissolved and Entrained Gases (Gamma Emitters)	$1x10^{-5}$
			I-131	$1x10^{-6}$

TABLE 12.3-1 (Continued)

RADIOACTIVE LIQUID WASTE SAMPLING AND ANALYSIS PROGRAM

TABLE NOTATIONS

(1) The LLD is defined, for purposes of these sections, as the smallest concentration of radioactive material in a sample that will yield a net count, above system background, that will be detected with 95% probability with only 5% probability of falsely concluding that a blank observation represents a "real" signal.

For a particular measurement system, which may include radiochemical separations:

$$LLD = \frac{4.66 s_b}{E \times V \times 2.22 \times 10^6 \times Y \times \exp(-\lambda \Delta t)}$$

Where:

LLD = the lower limit of detection (microCuries per unit mass or volume),

s_b = the standard deviation of the background counting rate or of the counting rate of a blank sample as appropriate (counts per minute),

E = the counting efficiency (counts per disintegration),

V = the sample size (units of mass or volume),

2.22×10^6 = the number of disintegrations per minute per microCurie,

Y = the fractional radiochemical yield, when applicable,

λ = the radioactive decay constant for the particular radionuclide (sec^{-1}), and

Δt = the elapsed time between the midpoint of sample collection and the time of counting (sec).

Typical values of E, V, Y, and Δt should be used in the calculation.

Alternative LLD Methodology

An alternative methodology for LLD determination follows and is similar to the above LLD equation:

$$LLD = \frac{(2.71 + 4.65\sqrt{B}) \times Decay}{E \times q \times b \times Y \times t \, (2.22 \times 10^6)}$$

TABLE 12.3-1 (Continued)

RADIOACTIVE LIQUID WASTE SAMPLING AND ANALYSIS PROGRAM

TABLE NOTATIONS

Where:

B = background sum (counts)

E = counting efficiency, (counts detected/disintegration's)

q = sample quantity, (mass or volume)

b = abundance, (if applicable)

Y = fractional radiochemical yield or collection efficiency, (if applicable)

t = count time (minutes)

$2.22X10^6$ = number of disintegration's per minute per microCurie

$2.71 + 4.65\sqrt{B} = k^2 + (2k \sqrt{2} \sqrt{B})$, and k = 1.645.

(k=value of the t statistic from the single-tailed t distribution at a significance level of 0.95 and infinite degrees of freedom. This means that the LLD result represents a 95% detection probability with a 5% probability of falsely concluding that the nuclide present when it is not or that the nuclide is not present when it is.)

Decay = $e^{\lambda\Delta t}$ $[\lambda RT/(1-e^{-\lambda RT})]$ $[\lambda T_d/(1-e^{-\lambda Td})]$, (if applicable)

λ = radioactive decay constant, (units consistent with Δt, RT and T_d)

Δt = "delta t", or the elapsed time between sample collection or the midpoint of sample collection and the time the count is started, depending on the type of sample, (units consistent with λ)

RT= elapsed real time, or the duration of the sample count, (units consistent with λ)

T_d = sample deposition time , or the duration of analyte collection onto the sample media, (units consistent with λ)

The LLD may be determined using installed radioanalytical software, if available. In addition to determining the correct number of channels over which to total the background sum, utilizing the software's ability to perform decay corrections (i.e. during sample collection, from sample collection to start of analysis and during counting), this alternate method will result in a more accurate determination of the LLD.

It should be recognized that the LLD is defined as a before the fact limit representing the capability of a measurement system and not as an after the fact limit for a particular measurement.

TABLE 12.3-1 (Continued)

RADIOACTIVE LIQUID WASTE SAMPLING AND ANALYSIS PROGRAM

TABLE NOTATIONS

(2) A batch release is the discharge of liquid wastes of a discrete volume. Prior to sampling for analyses, each batch shall be isolated, and then thoroughly mixed to assure representative sampling.

(3) A composite sample is one in which the quantity of liquid sampled is proportional to the quantity of liquid waste discharged and in which the method of sampling employed results in a specimen that is representative of the liquids released.

(4) A continuous release is the discharge of liquid wastes of a nondiscrete volume, e.g., from a volume of a system that has an input flow during the continuous release.

(5) To be representative of the quantities and concentrations of radioactive materials in liquid effluents, samples shall be collected continuously whenever the effluent stream is flowing. Prior to analyses, all samples taken for the composite shall be thoroughly mixed in order for the composite sample to be representative of the effluent release.

(6) Not required unless the Essential Service Water RCFC Outlet Radiation Monitors RE-PR002 and RE-PR003 indicates measured levels greater than $1x10^{-6}$ μCi/ml above background at any time during the week.

(7) The principal gamma emitters for which the LLD specification applies include the following radionuclides: Mn-54, Fe-59, Co-58, Co-60, Zn-65, Mo-99, Cs-134, Cs-137, and Ce-141. Ce-144 shall also be measured, but with an LLD of 5E-06. This list does not mean that only these nuclides are to be considered. Other gamma peaks that are identifiable, together with those of the above nuclides, shall also be analyzed and reported in the Radioactive Effluent Release Report pursuant to Section 12.6.2, in the format outlined in Regulatory Guide 1.21, Appendix B, Revision 1, June 1974.

(8) A continuous release is the discharge of dissolved and entrained gaseous waste from a nondiscrete liquid volume.

12.3.2 Dose

Operability Requirements

12.3.2.A The dose or dose commitment to a MEMBER OF THE PUBLIC from radioactive materials in liquid effluents released, from each unit, to UNRESTRICTED AREAS (see Braidwood Station ODCM Annex, Appendix F, Figure F-1) shall be limited:

1. During any calendar quarter to less than or equal to 1.5 mrems to the whole body and to less than or equal to 5 mrems to any organ, and

2. During any calendar year to less than or equal to 3 mrems to the whole body and to less than or equal to 10 mrems to any organ.

Applicability: At all times.

Action:

1. With the calculated dose from the release of radioactive materials in liquid effluents exceeding any of the above limits, prepare and submit to the Commission within 30 days, pursuant to 10 CFR 50 Appendix I, Section IV.A, a Special Report that identifies the cause(s) for exceeding the limit(s) and defines the corrective actions that have been taken to reduce the releases and the proposed corrective actions to be taken to assure that subsequent releases will be in compliance with the above limits.

Surveillance Requirements

12.3.2.B Cumulative dose contributions from liquid effluents for the current calendar quarter and the current calendar year shall be determined in accordance with the methodology and parameters in the ODCM at least once per 31 days.

Bases

12.3.2.C This section is provided to implement the requirements of Sections II.A, III.A and IV.A of Appendix I, 10 CFR 50. The Operability Requirements implement the guides set forth in Section II.A of Appendix I. The ACTION statements provide the required operating flexibility and at the same time implement the guides set forth in Section IV.A of Appendix I to assure that the releases of radioactive material in liquid effluents to UNRESTRICTED AREAS will be kept "as low as is reasonably achievable." The dose calculation methodology and parameters in the ODCM implement the requirements in Section III.A of Appendix I that conformance with the guides of Appendix I be shown by calculational procedures based on models and data, such that the actual exposure of a MEMBER OF THE PUBLIC through appropriate pathways is unlikely to be substantially underestimated.

The equations specified in the ODCM for calculating the doses due to the actual release rates of radioactive materials in liquid effluents are consistent with the methodology provided in Regulatory Guide 1.109, "Calculation of Annual Doses to Man From Routine Releases of Reactor Effluents For the Purpose of Evaluating Compliance with 10 CFR 50, Appendix I" Revision 1, October 1977 and Regulatory Guide 1.113, "Estimating Aquatic Dispersion of Effluents from Accidental and Routine Reactor Releases for the Purpose of Implementing Appendix I," April 1977.
This section applies to the release of radioactive materials in liquid effluents from each reactor at the site. When shared Radwaste Treatment Systems are used by more than one unit on a site, the wastes from all units are mixed for shared treatment; by such mixing, the effluent releases cannot accurately be ascribed to a specific unit. An estimate should be made of the contributions from each unit based on input conditions, e.g., flow rates and radioactivity concentrations, or, if not practicable, the treated effluent releases may be allocated equally to each of the radioactive waste producing units sharing the Radwaste Treatment System. For determining conformance to Operability Requirements, these allocations from shared Radwaste Treatment Systems

are to be added to the releases specifically attributed to each unit to obtain the total releases per unit.

12.3.3 Liquid Radwaste Treatment System

Operability Requirements

12.3.3.A The Liquid Radwaste Treatment System shall be OPERABLE and appropriate portions of the system shall be used to reduce releases of radioactivity when the projected doses due to the liquid effluent, from each unit, to UNRESTRICTED AREAS (see Braidwood Station ODCM Annex, Appendix F, Figure F-1) would exceed 0.06 mrem to the whole body or 0.2 mrem to any organ in a 31-day period.

Applicability: At all times.
Action:

1. With radioactive liquid waste being discharged without treatment and in excess of the above limits and any portion of the Liquid Radwaste Treatment System not in operation, prepare and submit to the Commission within 30 days, pursuant to 10 CFR 50 Appendix I, Section IV.A, a Special Report that includes the following information:

   a. Explanation of why liquid radwaste was being discharged without treatment, identification of any inoperable equipment or subsystems, and the reason for the inoperability,

   b. Action(s) taken to restore the inoperable equipment to OPERABLE status, and

   c. Summary description of action(s) taken to prevent a recurrence.

Surveillance Requirements

12.3.3.B.1 Doses due to liquid releases from each unit to UNRESTRICTED AREAS shall be projected at least once per 31 days in accordance with the methodology and parameters in the ODCM when the Liquid Radwaste Treatment System is not being fully utilized.

12.3.3.B.2 The installed Liquid Radwaste Treatment System shall be considered OPERABLE by meeting Sections 12.3.1.A and 12.3.2.A.

Bases

12.3.3.C The OPERABILITY of the Liquid Radwaste Treatment System ensures that this system will be available for use whenever liquid effluents require treatment prior to release to the environment. The requirement that the appropriate portions of this system be used when specified provides assurance that the releases of radioactive materials in liquid effluents will be kept "as low as is reasonably achievable". This section implements the requirements of 10 CFR 50.36a, General Design Criterion 60 of Appendix A to 10 CFR 50 and the design objective given in Section II.D of Appendix I to 10 CFR 50.

The specified limits governing the use of appropriate portions of the Liquid Radwaste Treatment System were specified as a suitable fraction of the dose design objectives set forth in Section II.A of Appendix I, 10 CFR 50, for liquid effluents.
This section applies to the release of radioactive materials in liquid effluents from each unit at the site. When shared Radwaste Treatment Systems are used by more than one unit on a site, the wastes from all units are mixed for shared treatment; by such mixing, the effluent releases cannot accurately be ascribed to a specific unit. An estimate should be made of the contributions from each unit based on input conditions, e.g., flow rates and radioactivity concentrations, or, if not practicable, the treated effluent releases may be allocated equally to each of the radioactive waste producing units sharing the Radwaste Treatment System. For determining conformance to Operability Requirements, these allocations from shared Radwaste Treatment Systems are to be added to the releases specifically attributed to each unit to obtain the total releases per unit.

Radiological Environmental Monitoring Program (REMP)

Braidwood ODCM Table 12.5-1 section 3.a, Ground / well water specifies that samples from two sources are required only if they are likely to be affected. Note (6) of ODCM Table 12.5-1 clarifies that groundwater samples shall be taken when this source is tapped for drinking or irrigation purposes in areas where the hydraulic gradient or recharge properties are suitable for contamination. Per discussion with Conestoga-Rovers & Associates and the Exelon Hydrologist, onsite groundwater at Braidwood meets the above criteria. There are drinking water wells in close proximity of the site that could be affected. However, there are no specific groundwater sample locations identified in the REMP. This requirement should be reviewed to determine the groundwater monitoring required to meet the requirements of Table 12.5-1.

Review of Braidwood ODCM Table 11-1 section 3.a, Ground / well water indicates that there are (5) drinking water wells currently being monitored.
Braidwood ODCM Table 12.5-1 Section 3.a and note (6) to the table discusses the need for groundwater monitoring when the irrigation pathway is a credible pathway. The hydraulic gradient at Braidwood indicates that shallow wells could become contaminated. ODCM Section 4.3 states that the only liquid pathways used are the potable water and fish ingestion pathways. The irrigation to food crop pathway associated with the groundwater contamination should be evaluated. (CA11)

Monitoring for other nuclides

40 CFR 141 and 35 IAC 620 specify limits on radionuclides other than tritium. As part of Braidwood's recovery plan, gamma-emitting fission and activation products as well as other beta-emitting nuclides (Strontium-89, and Strontium-90) are being analyzed. The gamma-emitting nuclide analytical results indicate normal background levels. Strontium-89 and Strontium-90 results indicate normal background levels.

Generic Chapters
Revision 3
January, 2002

Table 2-1
Regulatory Dose Limit Matrix

REGULATION	DOSE TYPE	DOSE LIMIT(s)[3]		ODCM EQUATION
Liquid Releases:		(quarterly)	(annual)	
10 CFR 50 App. I[3]	Whole (Total) Body Dose (per reactor unit)	1.5 mrem	3 mrem	A-17
	Organ Dose (per reactor unit)	5 mrem	10 mrem	A-17
Technical Specifications	The concentration of radioactivity in liquid effluents released to unrestricted areas	Ten (10) times the concentration values listed in 10 CFR 20 Appendix B; Table 2, Column 2, Table C-6 of ODCM Appendix C for Noble Gases		A-21
Total Doses [1]:				
10 CFR 20.1301 (a)(1)	Total Effective Dose Equivalent [4]	100 mrem/yr		A-25
10 CFR 20.1301 (d) and 40 CFR 190	Total Body Dose	25 mrem/yr		A-25
	Thyroid Dose	75 mrem/yr		A-25
	Other Organ Dose	25 mrem/yr		A-25
Other Limits [2]:				
40 CFR 141	Total Body Dose Due to Drinking Water From Public Water Systems	4 mrem/yr		A-17
	Organ Dose Due to Drinking Water From Public Water Systems	4 mrem/yr		A-17

[1] These doses are calculated considering all sources of radiation and radioactivity in effluents.

[2] These limits are not directly applicable to nuclear power stations. They are applicable to the owners or operators of public water systems. However, the RETS of some of the Exelon Nuclear power stations require assessment of compliance with these limits. For additional information, see Section A.6 of Appendix A.

[3] Note that 10 CFR 50 provides design objectives not limits.

[4] Compliance with 10 CFR 20.1301(a)(1) is demonstrated by compliance with 40 CFR 190. Note that it may be necessary to address dose from onsite activity by members of the public as well.

Attachment 11

Root Cause Report Quality Checklist

A.	Critical Content Attributes	YES	NO
1.	Is the condition that requires resolution adequately and accurately identified?	X	
2.	Are inappropriate actions and equipment failures (causal factors) identified?	X	
3.	Are the causes accurately identified, including root causes and contributing causes?	X	
4.	Are there corrective actions to prevent recurrence identified for each root cause and do they tie DIRECTLY to the root cause? AND, are there corrective actions for contributing cause and do they tie DIRECTLY to the contributing cause?	X	
5.	Have the root cause analysis techniques been appropriately used and documented?	X	
6.	Was an Event and Causal Factors Chart properly prepared?	X	
7.	Does the report adequately and accurately address the extent of condition in accordance with the guidance provided in Attachment 3 of LS-AA-125-1003, Reference 4.3?	X	
8.	Does the report adequately and accurately address plant specific risk consequences?	X	
9.	Does the report adequately and accurately address programmatic and organizational issues?	X	
10.	Have previous similar events been evaluated? Has an Operating Experience database search been performed to determine whether the problem was preventable if industry experience had been adequately implemented?	X	

Attachment 11

Root Cause Report Quality Checklist

B.	**Important Content Attributes**		
1.	Are all of the important facts included in the report?	X	
2.	Does the report explain the logic used to arrive at the conclusions?	X	
3.	If appropriate, does the report explain what root causes were considered, but eliminated from further consideration and the bases for their elimination from consideration?	X	
4.	Does the report identify contributing causes, if applicable?	X	
5.	Is it clear what conditions the corrective actions are intended to create?	X	
6.	Are there unnecessary corrective actions that do not address the root causes or contributing causes?		X
7.	Is the timing for completion of each corrective action commensurate with the importance or risk associated with the issue?	X	
C.	**Miscellaneous Items**		
1.	Did an individual who is qualified in Root Cause Analysis prepare the report?	X	
2.	Does the Executive Summary adequately and accurately describe the significance of the event, the event sequence, root causes, corrective actions, reportability, and previous events?	X	
3.	Do the corrective actions include an effectiveness review for corrective actions to prevent recurrence?	X	
4.	Were **ALL** corrective actions entered and verified to be in Action Tracking?	X	
5.	Are the format, composition, and rhetoric acceptable (grammar, typographical errors, spelling, acronyms, etc.)?	X	

Attachment 12

Vacuum Breaker #3 (VB-3) and Vacuum Breaker 2 (VB-2) Event Timeline

Vacuum Breaker #3 (VB-3)

December 1997

- VB-3 was inspected (PM 00079293) with no water leakage noted.

December, 3 to 4, 1998

- VB-3 was discovered leaking, due to water hammer failure of the air vent valve line **(RC 38237-02)**. The Problem Identification Form (PIF) for this event (A1998-04324) was closed to no concern, based on the water being contained onsite and apparently personnel not aware of a tritium concern **(Root Cause 4).** The PIF stated that the water was in the ditch, which Exelon owns. PIF A1998-04324 stated the repair (temporary) to stop the leak was completed within 24 hours (12/05/1998) under WO 98127749. This section of ditch is blocked at both ends. The size/amount of leakage was not recorded due to a lack of monitoring instrumentation **(Other Issue "a"),** but was estimated in 2000 to be similar to the 2000 VB-2 leakage at approximately 3 million gallons over a 30-day period. No integrated spill response procedure was in place to guide adequate station response. **(Root Cause 3)**

December 1998 Spill Conclusion

In 1998, VB-3 failed and released approximately three million gallons producing standing surface water on Braidwood property. Problem Identification Form (PIF) A1998-04324 [equivalent to today's Issue Report (IR)] was created to document and address this spill. The response to this event was to isolate the valve and repair the valve as soon as possible. The Braidwood NPDES Coordinator was notified and determined that there were no environmental concerns because the water had not reached a waterway. The environmental procedures concentrate on NPDES compliance associated with oil or hazardous materials and by design, provide no guidance on radiological spills (Failed Barriers 1 & 2).

The Reportability Manual (LS-AA-1020 & 1110) does not reflect ODCM REMP/RETS reporting requirements for unplanned release paths (Failed Barriers 7-11). Also, these procedures do not reflect 35 IAC 620 groundwater tritium requirements (Failed Barriers 7-11). At the time, Operations personnel believed (through interviews) that the water leaking from the CW B/D VB was procedurally treated and approved for radiological release to the environment (Kankakee River) and they assumed it to be radiologically acceptable if it leaked to the ground. Engineering interviews indicated that they were aware of diluted radioactive waste effluent in the CW B/D line, but since there had been no training for the requirements or the implications of a CW B/D water spill, the creation of a work request and issue report would be an adequate response to correct the leak during the next scheduled work week.

The Event Screening Committee (the equivalent of today's Braidwood Senior Management Review Committee) reviewed PIF A1998-04324 and assigned no actions to inquire into or address radiological concerns. As a consequence, no action items were created to track the characterization, remediation and documentation of this spill. Radiological concerns were not recognized. There was no documentation that any spill remediation was performed. A root cause for the ineffective response was weak management review and oversight of spill response activities (**Root Cause 4**). In this event , the knowledgeable personnel with the radiological expertise were not brought to bear. The root cause was determined to be a lack of integrated procedural guidance to ensure proper recognition, evaluation, and timely mitigation of the spill events (**Root Cause 3**) to ensure proper identification, timely mitigation and evaluation of the spill events, including knowledge of local hydrology, the impact of low-level tritium leaks, and groundwater regulations.

Documentation associated with the response does not indicate recognition that a potential radioactive spill had occurred. Had it been recognized that the 1998 release of tritium to an unplanned location (the field in the vicinity of VB-3) was a radiological release, a more rigorous characterization and remediation response may have been initiated. A lack of recognition by the Operations Department personnel (who initiate and secure the release of processed radioactive waste into the CW B/D System) and/or the Radiological Protection personnel (who sample and analyze the release tanks prior to concurring with the release), would be a missed opportunity.

Additionally, the 1998 Annual Effluent Report did not contain an evaluation of the vacuum breaker radioactivity released and did not contain the associated evaluation of the dose to the public (IR 455079) & (CA-15). No documentation was located that implied a recognition of vacuum breaker leakage impact on the requirements of the ODCM, REMP, and 10CFR50.75(g).

The root cause of the large volume leaks in 1998 and 2000 is documented in Root Cause Report (RCR) 38237, which determined that the Circulating Water (CW) Blowdown (B/D) Vacuum Breaker (VB) Valves had inadequate preventative maintenance programs and inadequate design configuration (**Root Cause 1).**

November 15, 2000

- Condition Report (CR) A2000-04389 was written which stated that the 1998 response to PIF A1998-04324 was inadequate, as a result of Root Cause Report (RCR) 38237/CR A2000-04281. CR A2000-04389 resulted in an action to Radiation Protection to perform a radiological evaluation under 10 CFR 50.75(g). June 18, 2001

- CR A2001-01806 reported VB-3 leaking. WC-AA-106 did not have tritium concerns integrated into the work prioritization. At this time, there was no guidance in the CW B/D procedures to secure radiological releases when known leaks were discovered. **(Root Cause 3)**

  Note: Little to no information could be found in PIF's or WR/WO's for this event. Therefore, little data could be retrieved by this Root Cause Investigation Team (IR 428868) other than from personnel interviews.

July 21, 2001

- CR A2000-04389's 10 CFR 50.75(g) Radiological Assessment Report was completed based on samples obtained in April 2001. In retrospect, the 1998 VB-3 spill site was inadequately characterized, due to the lack of groundwater assessment for tritium concentrations. Therefore, the evaluation erroneously concluded that there was no further action required.

July 23, 2001

- Revision 2 of WO 98127749 to repair VB-3 is authorized for work by Operations. The WO comments stated that leaking water prevented work completion. The WO did not contain precautions regarding tritium leakage, due to ATI 106767-04 (May 2002) comments not being incorporated into the WO. ***(Other Issue "b")***

December 2001

- VB-3 was inspected (WO 99284438) with no water leakage noted.

May 4, 2002

- VB-3 pilot (air release) valve seat was discovered leaking water. WO 004402131 and IR 106767 were written.

Attachment 12

Vacuum Breaker #3 (VB-3) and Vacuum Breaker 2 (VB-2) Event Timeline

May 20, 2002

- Revision 2 of WO 98127749 to repair the isolation valve for VB-3 was completed, with no mention of radiological controls for the water discovered in the vacuum breaker pit. **(Root Cause 3)**

August 29, 2003

- Water was found in the VB-3 valve pit during walkdown surveillance. WR 00110407 and IR 173688 were written. The IR indicates water is most likely groundwater intrusion into the pit. There was no observed leakage from VB-3.

March 17, 2005

- The Illinois Environmental Protection Agency (IEPA) contacted Exelon concerning an investigation of tritium concentrations in wells near Braidwood Station in preparation for the Godley public hearing. Sampling to investigate this report was commenced. (IR 328451)

November 30, 2005

- Issue Report (IR) 428868 reports tritium concentrations from what appears to be the area of the 1998 spill, have migrated offsite with a potential to affect the public via tritiated groundwater. ***(EVENT)***

Vacuum Breaker 2 (VB-2)

December 1996

- VB-2 was inspected (PM 00079293) with no water leakage noted.

January 5, 1998

- Water leak discovered on the VB-2 pilot (air release) valve seat. WR 9800691 was written.

Attachment 12

Vacuum Breaker #3 (VB-3) and Vacuum Breaker 2 (VB-2) Event Timeline

May 24, 2000

- VB-2 found leaking. Issue tracked via WR 9800691.

November 6, 2000 14:30

- The Braidwood National Pollutant Discharge Elimination System (NPDES) Coordinator received a call from the Illinois Environmental Protection Agency (IEPA) regarding standing water in a ditch immediately adjacent to private property along the south side of Smiley Road. An area resident had reported the water and noted that the water had been present in the ditch for approximately 7-10 days prior to IEPA notification. Suspecting a faulty vacuum breaker, the NPDES Coordinator notified the Shift Manager and Outage Control Center (OCC) Director of the IEPA notification.

November 6, 2000 15:00

- The Braidwood NPDES Coordinator walked down the Circulating Water Blowdown system and identified that the water was coming from a valve vault that houses VB-2. The NPDES Coordinator assessed the site and concluded that the water was confined to site property which included the ditch along the south side of Smiley Road.

- The Braidwood NPDES Coordinator notified the IEPA of his findings regarding the water source and the boundaries of the discharge. Station NPDES monitoring requirements were discussed and the IEPA requested no additional sampling. The Braidwood NPDES Coordinator determined that there were no NPDES concerns since the water was contained and not discharging to "Waters of the State".

- The VB-2 leakage was estimated to be a maximum of 3 million gallons. This leakage was the result of corrosion of the vacuum breaker assembly and water hammer, which broke the float in VB-2, exposing an 8" opening.

Attachment 12

Vacuum Breaker #3 (VB-3) and Vacuum Breaker 2 (VB-2) Event Timeline

November 6, 2000 16:00 -17:00

- A meeting was held with Braidwood Senior Management, the Shift Manager and the Outage Control Center (OCC) staff. The Braidwood NPDES Coordinator briefed the attendees on the results of his field observations of the area surrounding the vacuum breaker valve. Braidwood Senior Management was also briefed on the discussions between the Braidwood NPDES Coordinator and the IEPA. Braidwood Senior Management directed the following actions be taken:
  1. Operating personnel were to evaluate water inventories and to explore potential alternate release options.
  2. Isolate the CW B/D system
  3. Make preparations to take the CW B/D system out of service, drain the piping section and replace the failed vacuum breaker valve.

- The CW B/D system was then isolated in preparation for draining and repairs. There was no discussion at this time of any need to sample for radioactivity in the water that had been discharged. The thought process was that any radioactivity in the water had been diluted per procedure and was acceptable for discharge to the environment (i.e., the Kankakee River). [This is based on Operations Department personnel interviews.]

November 7, 2000 06:15

- The Braidwood Operations Manager notified the Braidwood Radiation Protection (RP) Manager that there was a blowdown line leak and that RP was to meet with the Braidwood Chemistry Manager to look at potential alternate radioactive release paths. The reason for this request was that radioactive releases would not be possible via the blowdown system while blowdown was isolated for repairs to VB-2.

- Following this phone conversation, the Braidwood RP Manager notified the Braidwood RP Technical Superintendent regarding the need to collect samples of available water.

Attachment 12

Vacuum Breaker #3 (VB-3) and Vacuum Breaker 2 (VB-2) Event Timeline

November 7, 2000 08:00

- A decision to conduct confirmatory sampling of the water leaking from the manway cover of the vacuum breaker structure was made. The sample was taken at approximately 0845 and the results of the gamma isotopic analysis indicated no detectable radioactivity. Isotopic analysis indicated no detectable tritium.

- Braidwood chemistry manager contacts corporate environmental and asks them to report to the site to help assess the event.

- Decision is made by Braidwood Senior Management to sample both soil and water at the vacuum breaker.

November 7, 2000 08:30

- Mechanical Maintenance Department (MMD) personnel with assistance from System Engineering pumped out the VB-2 vault back into the B/D line and began draining the blowdown piping to facilitate work on VB-2.

November 7, 2000 11:30

- Braidwood RP received information that the leak may have occurred for a period of 7-10 days and that the water that leaked was from the circulating water blowdown line, which carries the liquid radiological discharges from the station to the river.

November 7, 2000 12:00

- After the CW B/D line had drained sufficiently, the entire VB-2 isolation valve and vacuum breaker assembly was replaced.

Attachment 12

Vacuum Breaker #3 (VB-3) and Vacuum Breaker 2 (VB-2) Event Timeline

November 7, 2000 12:30

- A decision was made to initiate soil sampling in the vicinity of the vacuum breaker structure, and to obtain a water sample from the standing water that was onsite, but near the Smiley Road ditch.

November 7, 2000 13:00

- Braidwood RP Manager and Station Manager discuss and agree to additional sampling. Plan was approved.

November 7, 2000 18:00

- Braidwood management talked with local residents to explain the issue.

November 7, 2000 19:00

- The results of the samples from November 7, 2000, were discussed with corporate Generation Support Department (GSD) RP Manager. Corporate GSD agreed to discuss the issue with the corporate GSD General Manager.

November 7, 2000 19:45

- The Station Manager and Site Vice-President (VP) were notified of the sample results. A total of 5 soil samples were obtained within approximately 30 feet of the vacuum breaker VB-2 structure, and 2 of the 5 soil samples had detectable levels of radioactivity. The onsite soil sample obtained near the Smiley Road ditch was analyzed indicated no gamma radioactivity, and water analysis from the location indicated tritium at 35,000 pCi/L.

November 7, 2000 21:15

- Circ water blowdown is restored.

Attachment 12

Vacuum Breaker #3 (VB-3) and Vacuum Breaker 2 (VB-2)
Event Timeline

November 8, 2000 08:30

- The Braidwood RP Manager discussed the sample results on the morning call.

November 8, 2000 14:00

- The Braidwood RP Manager, Chemistry Manager, Regulatory Assurance Manager, Station Manager, and Site VP met to discuss the current status, next steps, and sampling for the event.

November 8, 2000 16:00

- Additional onsite sampling of the standing water in the area leading to the Smiley Road ditch was performed. Four water samples were taken and results indicated tritium levels ranging from 35,000 to 53,000 pCi/L. No gamma isotopic activity was detected in the water.

November 8, 2000 18:00

- Conference call between site and corporate regarding test results and proposed actions.

November 9, 2000 10:00

- A conference call was held with the Site Management and Corporate Personnel to finalize and approve an Offsite Sampling Plan, a Remediation Plan, and a Communications Plan. At 12:00, discussions were held with site and regional NRC personnel. At 1210, notification of the offsite release was made to Will County authorities and to the Reed Township Highway Commissioner. At 12:45, RP was dispatched to obtain water samples from the Smiley Road ditch.

Attachment 12

Vacuum Breaker #3 (VB-3) and Vacuum Breaker 2 (VB-2) Event Timeline

November 9, 2000 14:00

- Four water samples were obtained from the Smiley Road ditch. Gamma isotopic analysis indicated and the tritium analyses ranged from 19,000 pCi/L to 25,000 pCi/L NQPF. Teledyne Isotopes Midwest Laboratory also analyzed these samples with similar results.

November 9, 2000 17:30

- The NRC Regional Office and Illinois Department of Nuclear Safety (IDNS) were notified of the Smiley Road ditch sample analyses results.

November 10, 2000 01:00

- IDNS came to the site to take (4) samples from the Smiley Road ditch.

November 10, 2000 11:00

- Pumping of the water back to the blowdown line commenced. Pumping continued using a 600 gpm pump, approximately 18 hours per day.

- Corporate led remediation team formed and OP-AA-101-503 "NGG Issue Management Worksheet" was entered. Attachment 2 (action plan) of this procedure was created and approved.

November 2000 Spill Conclusions

In 2000, VB-2 failed and released approximately three million gallons to the Braidwood Station grounds. A local resident observed and reported the spill to the Illinois Environmental Protection Agency (IEPA), who in turn notified the Braidwood Station National Pollutant Discharge Elimination System (NPDES) Coordinator. The NPDES Coordinator wrote PIF A2000-04281 and notified the Illinois Department of Nuclear Safety (IDNS), the Illinois Emergency Management Agency (IEMA) and Braidwood Senior Management. The Braidwood Radiation Protection (RP) Manager and the RP Technical Superintendent discussed the need to collect samples of available water at VB-2. The sample results indicated >20,000 pCi/L tritium was present in the spilled water. The immediate response to this event was to shutdown the blowdown system, repair the valve as soon as possible, and engage Senior Corporate Management to create a spill response plan.

Attachment 12

Vacuum Breaker #3 (VB-3) and Vacuum Breaker 2 (VB-2) Event Timeline

A Senior Corporate Manager was chosen to assemble and direct an Issues Management Team (IMT). Although knowledgeable personnel supported the IMT, there was no integrated procedure in place to ensure that all necessary actions were completed **(Root Cause 3)**. As a result, the groundwater tritium was not properly characterized and remediated.

The IMT entered four (4) Corporate procedures, which provide guidance to identify, evaluate, remediate and communicate the radiological concerns. The four (4) procedures were:

- NSP-RP-6101, "*10 CFR 50.75(g)(1) Documentation Requirements*"
- CWPI-NSP-1-1, "*CAP Process Manual of Common Work Practice Instructions – Instruction on Event Response Guidelines*"
- OP-AA-101-501, "*NGG Significant Event Reporting*"
- OP-AA-101-503, "*NGG Issues Management*".

However, no historical documentation could be located to demonstrate that the procedures (other than NSP-RP-6101) were fully executed. There is no evidence of the use of Passport for the documentation of the IMT plans and activities as required by OP-AA-101-503, "NGG Issues Management". This root cause team interviewed (by telephone) the Corporate Senior Manager who was assigned to manage the Issues Management Team. He was questioned concerning the execution of the IMT's responsibilities. The Corporate Senior Manager had little recollection of the details of the team's response. Although that Corporate Senior Manager had the responsibility to manage the IMT's completion of characterization and remediation plans and would normally be held accountable, he is no longer employed by Exelon. This indicates weak management review and oversight of spill response activities. (**Root Cause 4**)

The IMT developed separate soil sampling plans and water sampling plans flowcharts (decision trees). For soil, all documentation was done within the station 10 CFR 50.75(g) procedure, NSP-RP-6101. For water, the sampling plan included a review of the tritium in the water and implementation of a Remediation/Control Plan. Notes on the water sampling plan indicate that the team considered: 1) pumping the water back into the blowdown line and 2) well monitoring.

The IMT had also recognized the need to evaluate local hydrology for potential impact of the tritiated spill in groundwater as referenced in a contractor's proposal for the implementation of a Stage 1 and Stage 2 plan. Stage 1 included the installation of wells to assess the local hydrology to determine groundwater gradients and movement . This stage of the plan was executed by the IMT. Stage 2 of the plan included sampling of the groundwater to determine mixing model and surface infiltration into an aquifer. Stage 2 of the plan was not executed.

The water was pumped back into the B/D line on 11/10/00 and hydrology wells were installed in the area of the 2000 leak to characterize the local hydrology. The contractor report specified that the groundwater in the area of VB-2 would take 15 years to travel the 800 feet to reach the property line.

The report then clarifies that the flow velocity would not apply to the surface water that apparently flowed from the valve box, over the land surface, and to the ditch along the road.

The remediation efforts were halted after the surface water was pumped back into the B/D line Although no documentation exists for the basis behind the decision to not perform groundwater sampling, a review of IMT data and notes has lead the Root Cause Investigation Team to conclude that the following information was considered in the decision making process:

- The spilled water had already been approved for release. Therefore, it was already determined to meet concentration limits for release to the public. The team assessed the impact of the radiological spill against known reporting requirements. The Illinois Groundwater statute was absent from the list in the IMT notes (Causal Factor 4).
- The hydrology study indicated that it would be 15 years before groundwater in the area of VB-2 would migrate offsite to potentially impact offsite drinking water wells. At that rate, the tritium concentration would be below drinking water standards, potentially even below detectable levels, by the time it reached the site boundary due to radiological decay and, potentially, dilution. [Today, hydrology experts state that once the tritium enters the groundwater, dilution does not significantly occur.]

Further efforts included a 10 CFR 50.75(g) characterization study. The 2000 10 CFR 50.75(g) focused primarily on soil sampling. The 10 CFR 50.75(g) study does reference the tritium concentrations that were found in the standing water. The 10 CFR 50.75(g) study did not direct groundwater sampling for tritium nor assess the environmental impact of the spilled tritium (Failed Barrier 3). The 2000 RCR Team required an analysis of the 2000 leak 10 CFR 50.75(g) by an independent Certified Health Physicist and approval by Braidwood Senior Management, however, this analysis did not include tritium. As a result, the groundwater tritium went undetected until the 2005 tritium sampling discovered it. This indicates weak management review and oversight of spill response activities. (**Root Cause 4**)

The year 2000 leak from Vacuum Breaker (VB) 2, RCR # 38237 documented 5 CW B/D vacuum breaker spills. Two of these released a large volume of water. The root cause of these leaks was inadequate preventative maintenance programs and inadequate design configuration (**Root Cause 1).** Effectiveness Review (EFR) of the Corrective Actions to Prevent Recurrence (CAPRs) of large volume leaks determined that the CAPRs were effective at resolving the Root Cause. However, the Root Cause was narrowly defined, only evaluating the large volume valve leaks and not considering radiological impacts from the spills due to a lack of technical rigor (CAPR 3 and CAPR 5 address this issue).

Attachment 12

Vacuum Breaker #3 (VB-3) and Vacuum Breaker 2 (VB-2) Event Timeline

The 2000 Root Cause Report (RCR) Team discovered the large volume 1998 VB-3 leak and wrote PIF A2000-04281 to have the 1998 spill reviewed per procedure # NSP-RP-6101 for residual radioactivity under 10 CFR 50.75(g). The soil sampling conducted as part of the 10 CFR 50.75(g) process indicated similar deposited radionuclides in the soil as that found during the 2000 leak. However, tritium was not addressed (Failed Barrier 3).

Braidwood Senior Management and Exelon Corporate Senior Management did not track characterization and mitigation plans to completion during and following the year 2000 spill. Although the 2000 Annual Effluent Report did report the 2000 vacuum breaker leakage as an unplanned release, it did not contain a proper assessment of the dose to the public. The 1998 Annual Effluent Report was not amended to report the 1998 vacuum breaker leakage (discovered in 2000) and associated dose to the public (IR 455079) & (CA-15).

HU-AA-102 and -1212, Technical Human Performance Practices and Technical Task Risk/Rigor Assessment, Pre-Job Brief, Independent Third Party Review, and Post-Job Brief procedures have been instituted to improve technical rigor, questioning attitude, and attention to detail (**CAPR 3**). OP-AA-106-101-1002, Exelon Nuclear Issues Management, will be revised to: 1) improve Corrective Action Program (CAP) controls of Issue Management Teams, 2) utilize the tools and techniques of the Exelon HU-AA-102 and -1212, Technical Human Performance Practices and Technical Task Risk/Rigor Assessment, Pre-Job Brief, Independent Third Party Review, and Post-Job Brief procedures, 3) strengthen reporting requirements to station Senior Management, and 4) define station Senior Management responsibilities oversight and challenge of events and issues from initiation to final disposition (**CAPR 5**).

An email from an RP supervisor who attended an exit meeting for an NRC REMP (radiological effluent monitoring program) inspection (NRC Inspection Report Braidwood 2001-0005) provided the following information. The Nuclear Regulatory Commission (NRC) reviewed the 2000 Root Cause (RC 38237) (documented in NRC Inspection Report Braidwood 2001-0005) and had a recommendation to sample residential wells in the area of concern "just to see negative results from these locations to support future cleanup activities" (documented only in the email). A second comment from the NRC review was that the root cause only focused on the equipment issues and not on spill recovery aspects. No documentation could be found to show that the Issues Management Team or Braidwood Senior Management reacted to these NRC's observations. This response reflects a weak management review and oversight of spill response activities (**Root Cause 4**). A contributing cause to this overall event was a weak questioning attitude and an inadequate challenge culture by Braidwood Senior Management regarding the 17 CW B/D leaks over the 10 year period bridging 1996 to the present.