ATTACHMENT 16
Sheet 1 of 3
Significant Adverse Condition Investigation Report
Form CAP-NGGC-0205-16-6

EXECUTIVE SUMMARY

Action Request Number: 00268357

Event Date: February 29, 2008

Sponsoring Manager: Jeff Ferguson / Jerry Johnson

Investigation Team: Nancy Holley, Marty McGowan, Chuck Nelson, Mark Turkal, Mike Millinor, Jeremie Varnam, Louise England, Andy Wodarczyk, and Martin Souther

Summary of Event: Increasing trends of tritium concentration have been observed in Wells ESS-2C and ESS-16, located on the east side of the point where the Discharge Cooling Water Tunnels pass under the plant's security fence. The increasing trend of tritium concentration in these wells is dated back to the 2004 and 2005 timeframe. These wells had previously showed declining trends during 2003 following the implementation of corrective actions from NCR 26566, Degradation Observed in Storm Drain Piping. These wells have been monitored for tritium since their installation in 1995. These wells were installed based on hydrologist recommendations during the 1995 D'Appolonia review following a failed leak test of the RadWaste Effluent Line. This effluent line was repaired by lining the pipe in 1994 with subsequent Preventative Maintenance leak tests performed during each unit's refueling outage passing inspection. The Unit 2 Storm Drain piping that is routed to the Storm Drain Collector Basin (SDCB) passes close by to Wells ESS-2C and ESS-16. This piping is 36 inch concrete piping that is typical of storm drain piping used during plant construction. This Unit 2 Storm Drain piping was used to transport Unit 2 Air Wash overflow to the SDCB from the time of plant construction until June 2007. The average concentration of tritium that passed through this piping from 2000 through the isolation of Unit 2 Air Wash overflow in June 2007 was approximately 8,400,000 pCi/L with a maximum of 34,000,000 pCi/L.

Summary of Root and Select Cause(s): The environmental risk potential and consequences of utilizing storm drain piping to transport potentially contaminated liquids was not adequately understood. The risk potential and consequences of not performing preventative maintenance to replace the Unit 2 RadWaste liner were not fully understood or evaluated. Organizational decisions regarding groundwater monitoring were considered to be acceptable based on risk factors that were evaluated and understood in the history of the plant. As a result of these evaluations and decisions, the tritium plume that is known to be present in the switchyard and transformer yard area could not be effectively modeled to fully understand the path and movement of the plume and the current tracking and trending of monitoring wells was less than desirable which led to untimely discovery of increasing tritium trends in Wells ESS-2C and ESS-16.

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Summary of Corrective Action(s) to Prevent Recurrence (CAPR): Devise a long term tritium operational strategy for Brunswick Nuclear Plant that will include the following elements:

1. Discontinue tritium source from the Turbine Building HVAC system to the Storm Drain System and route to RadWaste.
2. Disposition and discontinue identified radioactive inputs into the Storm Drain System
3. Replace piping or pipe liner for the RadWaste Effluent Lines and develop standards for operation and maintenance.
4. Install monitoring wells within the Protected Area that will adequately model and assess tritium migration.
5. Conduct hydrology study of Protected area and evaluate contracted hydrologist recommendations with site management. Issue actions accordingly under NCR 268357.
6. Install new monitoring wells within the Owner Controlled Area to adequately model and assess tritium migration from the plant.
7. Conduct hydrology study of Owner Controlled area and evaluate contracted hydrologist recommendations with site management. Issue actions accordingly under NCR 268357.

Significant Adverse Condition Investigation Report

Form CAP-NGGC-0205-16-6

Action Request Number: 00268357
Facility: Brunswick Nuclear Plant
Unit: 0

Event Time: N/A
Event Date: February 29, 2008
Investigators: Nancy Holley
Jerry Johnson
Marty McGowan
Chuck Nelson
Mark Turkal
Mike Millinor
Jeremie Varnam
Louise England
Andy Wodarcyzk
Martin Souther

1. Event Description

Wells ESS-2C and ESS-16 were installed in 1995 based on recommendations following the 1994 Unit 2 RadWaste Effluent Line Leak. Tritium data has been collected at both of these locations since their installation. The data collected from Wells ESS-2C and ESS-16 has shown an increasing trend since the 2004 and 2005 timeframe. These wells are located on the east side of the point where the Discharge Cooling Water Tunnels pass under Brunswick Nuclear Plant's (BNP) security fence before heading to the Discharge Weir. The concentration of tritium for Well ESS-2C has increased from approximately 492,600 pCi/L in 2005 to 1,833,000 pCi/L in March 2008. The concentration of tritium for Well ESS-16 has increased from approximately 2,230 pCi/L in 2004 to 64,420 pCi/L in March 2008. Expanded well monitoring in this area is not possible since monitoring wells were not installed following the Unit 2 RadWaste Effluent Line leak since it was located within the BNP Transformer area. A tracking and trending initiative for Wells ESS-2C and ESS-16 failed to identify their increasing trend at an earlier time period.

2. Problem Description

Potentially radioactive liquids are periodically discharged from the plant via a series of underground piping. Piping includes lines used for routing of Storm Water, Cooling Water, RadWaste Effluent release, and other various building system drains. Piping utilized in the underground network for the Storm Drain System was constructed using material designed strictly for storm or sewage water transport and was never intended for the transport of radioactive liquids. Other piping, like the RadWaste Effluent lines, are used for the transport of potentially radioactive material and are constructed of material that is less susceptible for potential failure. This network of underground piping could provide a means of release of radioactive liquids to the environment if there is failure of the piping or if the piping is not designed to be leak tight. There have been known, suspected, and recorded failures of underground piping identified at Brunswick. Based on past failures, a series of monitoring wells were installed to track the migration of contaminated water.

Two of the wells installed have shown indications of radioactive tritium. The initial tritium concentrations measured after installation of Wells ESS-2C and ESS-16 in 1995 were approximately 46,000 pCi/L and 35,000 pCi/L, respectively. These wells were installed based on suggestions given from a contracted hydrologist firm, D'Appolonia, during the hydrology study performed following the Unit 2 RadWaste Effluent Line Leak. Tritium was chosen as the monitoring parameter since it was known to be present in RadWaste Effluents and is much more mobile compared to other radioactive isotopes present in the effluent. Currently, the tritium concentrations for Wells ESS-2C and ESS-16 are 1,833,000 pCi/L and 64,420 pCi/L, respectively. Based on the initial data and conditions from 1995, the significant increase in tritium concentrations that has been observed is unexpected. Tritium input sources into these wells must be evaluated and corrected to mitigate uncontrolled tritium release to the environment. Actions were implemented from conclusions made

during the Significant Adverse Condition Investigation for NCR 233865 that have established an Environmental monitoring program for tritium release to the public, however, efforts were primarily focused around the Storm Drain Stabilization Pond. NCR 233865 was generated and investigated to determine the tritium input source to manholes located near the plant Storm Drain Stabilization Pond. Although all sampling, analysis, and studies performed to date indicate that minimal impacts have been made to the public, site personnel, or drinking water sources, the potential for offsite migration must be further evaluated and understood for the impact to the public and for regulatory implications.

3. Investigation Summary

This investigation will determine:

- The Root Cause for the increasing tritium concentrations observed in Wells ESS-2C and ESS-16. This will be conducted by review and analysis of the operational history of possible inputs in the vicinity of these wells since plant construction.
- The extent and magnitude of this condition by ensuring a complete sample profile of existing and potential groundwater inputs and storm water sampling locations at BNP.
- The safety significance of this occurrence including radiological impact to members of the public.
- The long term and short term corrective actions necessary to minimize future tritium input sources to the environment. This NCR will include corrective actions from NCR 233865 for tritium input sources to manholes located near the Storm Drain Stabilization Pond that was originated May 22, 2007.

This investigation will also include a detailed review of available site data regarding the operational history of potential input sources that are located in the vicinity of the ESS-2C and ESS-16 wells and previous environmental program evaluation efforts to determine the circumstances that led to the current condition. CAP-NGGC-0205, Significant Adverse Condition Investigations, was utilized as a guidance document to structure this investigation and actions that will be required to prevent recurrence or provide correctives or enhancements. A refute and support methodology was utilized to identify failure modes, inappropriate acts, and equipment malfunctions.

Background

Tritium is a product of the nuclear fission process. Tritium production is increased when fuel failures or increased boron concentrations are present in reactor coolant. In an ideal situation, tritium would be contained in the steam cycle; however, various release mechanisms are seen at the site. Steam leaks in the Turbine Building (TB) systems and components provide a transport mechanism for tritium into the TB atmosphere and subsequently into the TB Heating, Ventilation, and Air Conditioning (HVAC) system. This mechanism is problematic during periods of known fuel leaks and elevated tramp concentrations (fission processes outside the fuel) which increase tritium concentration in the reactor coolant and the steam. Another potential transport mechanism of tritium from the reactor coolant is through the normal water cycle for the plant. Water is reclaimed and processed through the plant's RadWaste system. Various tanks that are used for processing are periodically released via a RadWaste Effluent Line.

The entire Turbine Building is maintained at a slightly negative pressure to ensure that unfiltered release of airborne radioactivity does not occur. At the time of observed increased tritium trends in Wells ESS-2C and ESS-16, the TB HVAC utilized a recirculation air ventilation system to provide effective air control to the building. Prior to the exhaust air being drawn into the supply fans, the warm and potentially radioactive air is cooled utilizing two spray coolers. The spray coolers take their suction from a water basin located at the bottom of the pleated filters that provide a mechanical scrubbing of the radioactive air. The spray cools the air that exits the exhaust fans. The cooled, moist air passes through the pleated filters to remove excess heat and contaminates, such as tritiated water. As more air passes through the filter, spray cooler water is reclaimed in the basin with removed contaminants. The constant recirculation provides a means of buildup of radioactive contaminants in the water. Water overflow, containing tritium, from this basin was originally routed to the Storm Drain system. Improvements were evaluated and suggested as seen in the American Nuclear Insurers (ANI) response to Recommendation LR97-06. A discussion was included to consider upgrading the entire TB HVAC system. This would include an evaluation of the replacement of the system with a coil cooling system which could route the condensate to RadWaste instead of the Storm Drain System.

As stated above, it is possible for tritium to be transported via the water processing cycle for the plant. The

RadWaste system reclaims water from the steam cycle as well as other inputs from plant in-leakage. Some of the processing tanks utilized by the RadWaste system, such as Waste Sample Tanks (WST), Floor Drain Sample Tanks (FDST), Detergent Drain Tanks (DDT), and Salt Water Release Tanks (SWRT), are periodically released from the site. WST and FDST will contain tritium as some of their input sources are from systems that have interfaces with Reactor Coolant. The release path for WST and FDST is through the RadWaste Effluent Line that ultimately will route to the Discharge Canal. No FDST releases have occurred since 1998.

The Storm Drain system is part of the underground piping network. The original design of the system was to route storm water drainage water directly to the Discharge Canal. As plant construction and design changes were implemented, the Storm Drain System began receiving inputs from Cooling Tower Blow down, Makeup Water Treatment Discharge, non-radioactive wastes, and overflow from the TB HVAC system. These inputs are then routed to the Storm Drain Collector Basin and eventually to the Storm Drain Stabilization Pond. Other inputs to the Storm Drain System include pump discharges of groundwater inleakage into Rattle Spaces or seismic protection spaces for the reactor buildings, other historical leaks and spills, condensate from Service Air and air conditioners in the Turbine Building, electrical manholes, leakage from building sumps, building drains, saltwater drains, roof drains, and fire water mains. One other input, Aux Boiler Blow down, will be elaborated on further into this report.

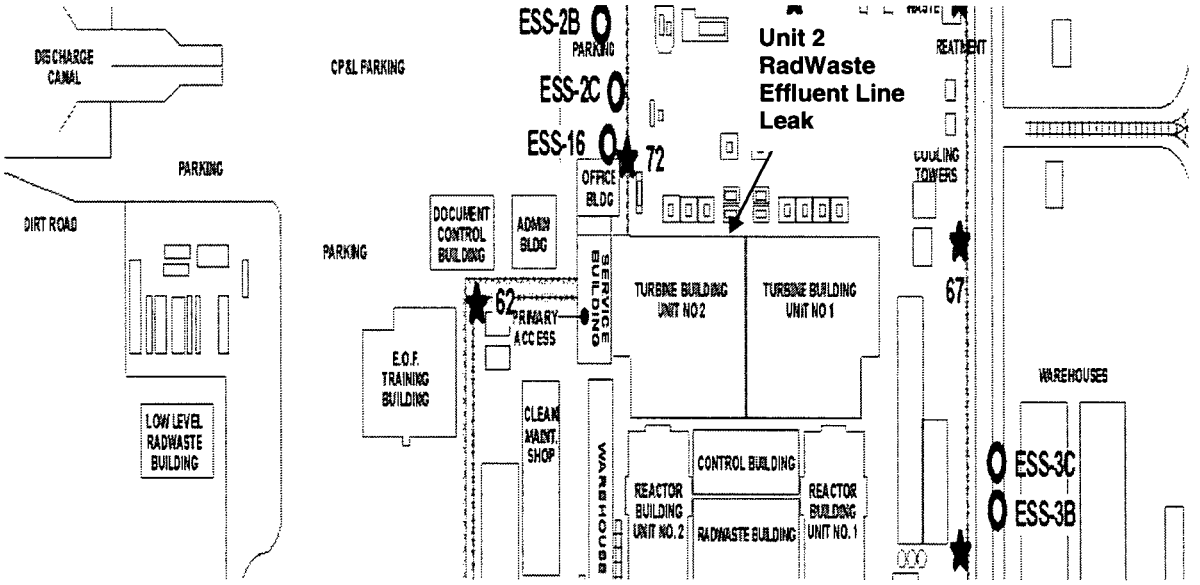
At the time of various design implementations during plant construction and startup, tritium migration was not well understood and was not monitored. Other design changes were implemented to utilize a treatment mechanism for the removal of suspended solids, oil, and grease. The Storm Drain Stabilization Pond was originally utilized as a spoil pond during the construction of the Intake Canal. It was constructed to the "as found" condition today to meet the Environmental Protection Agency (EPA) requirement for suspended solids, oil, and grease. The Storm Drain System routes to the Storm Drain Collector Basin and is then pumped toward the Storm Drain Stabilization Pond, where the water travels a tortuous path to filter out any unwanted contaminants, such as oil, grease, and suspended solids. The pond also serves as a mechanism for large volume dilution and retention time for settling of materials and decay of short-live isotopes.

As mentioned earlier, the Aux Boiler Blow down is routed to the Storm Drain System. It should be noted that in February 1980, an unplanned release of radioactivity occurred from the Auxiliary Boiler. The total activity released via the Boiler Fire Box and Smokestack was estimated to have been approximately 100 millicuries in the form of Cesium and other activation products. Tritium was not included in any documented analysis of this release. It was identified that contaminated liquids were entering the storm drains located near the Auxiliary Boiler. After the event, the Radiation Control and Test group began sampling the basin prior to each discharge to the Storm Drain Stabilization Pond for radioactivity. As a result of the unplanned release from the Auxiliary Boiler, United States Nuclear Regulatory Commission Office of Inspection and Enforcement Bulletin (IEB) 80-10 was issued which required each licensee to review facility design and operation to identify systems that are considered non-radioactive (or described as non-radioactive in the FSAR) but could possibly become radioactive through interfaces with radioactive systems. Also, each licensee was required to establish a routine sampling, analysis, or monitoring program for these systems in order to promptly identify any contaminating events which could lead to unmonitored, uncontrolled liquid or gaseous releases to the environment, including releases to on-site leaching fields or retention ponds. Safety analysis for the operation of the TB HVAC system as a radioactive contaminated system was also included in the hardcopy file. The analysis focused primarily on short lived isotopes such as iodine with no discussion of tritium. Another analysis was also contained with the IEB 80-10 and was generated to determine if there were safety questions not reviewed by extending the restricted area boundary to include the Storm Drain Stabilization Pond. The conclusion from the analysis indicated that the pond must be fenced as a restricted area to prevent personnel access and unnecessary exposure.

In 1987, the Unit 2 RadWaste Effluent line was suspected to be leaking and the line was repaired using a "wrap-around" patch. In 1994, the line was again assumed to be leaking after pressure testing of the Unit 2 RadWaste Effluent line failed. Since WST and FDST releases were known to occur utilizing this pathway, it can be assumed that water contaminated with tritium made its way to the groundwater contained onsite. The line was repaired by lining the piping system with Goodyear Plicord Red Flextra Hose. After the leak repairs in 1994, a groundwater study dated June 1995 was performed in the leak area and conclusions were captured in the Site Assessment Report Unit 2 RadWaste Effluent Line prepared for Carolina Power and Light by D'Appolonia. Wells ESS-2C and ESS-16 were installed in 1995 as part of a monitoring regime for a groundwater study. Wells ESS-2C and ESS-16 were installed at depths of approximately 25 feet. Based on

interviews with the Progress Energy Geologist who participated in the hydrology study and well installations following the RadWaste Effluent Line leak, other wells were not permitted to be installed at that time because of Site Management decisions as the locations of these wells would have been within the Transformer and Switchyard areas of the site. Wells ESS-2C and ESS-16 are located just outside this area and are east of the point where the Discharge Cooling Water Tunnels pass under the plant's security fence before heading towards the Discharge Weir (see Figure 1).

Figure 1
Locations of Wells ESS-2C and ESS-16



Wells ESS-2C and ESS-16 were sampled following their initial installation in 1995 and showed tritium concentrations of 46,000 pCi/L and 35,000 pCi/L, respectively. Neither of the wells showed any detectable gamma emitting radionuclides, which was expected. Tritium is a highly mobile radioactive isotope. Being an isotope of hydrogen that is part of the molecular structure of water, tritium flows in response to potential gradient in a manner identical to that of groundwater. It is typically not affected by adsorption, dispersion, chemical reaction with the aquifer matrix or other retarding forces.

Based on statements from the D'Appolonia report that was issued following the Unit 2 RadWaste Effluent Line leak, "movement of tritium has been from the point of leakage to the plant backfill." The point of leakage from the RadWaste Effluent line is contained within the backfill. The plant's backfill is a low elevation area around the plant that contains permeable soil. "The tritium will most likely move with the groundwater from the plant backfill to the Intake Canal." The Unit 2 RadWaste Effluent Line leak is located near the union of the Unit 1 and Unit 2 Turbine Buildings. Per the D'Appolonia report, the location of Wells ESS-2C and ESS-16 are along the edge of the plant backfill. Based on these locations and the statements from the D'Appolonia report, it is reasonable for tritium that was discharged into the groundwater via the known leak to migrate towards Wells ESS-2C and ESS-16. Well ESS-16 is also located along the pathway from the backfill towards the intake canal. It can also be expected that if tritium has entered the groundwater in the backfill that concentrations of tritium would be detected as the groundwater moves from the backfill towards the intake canal. Some references and statements from the D'Appolonia report have been questioned after thorough reviews from this investigation. These concerns are being addressed under Priority 1 NCR 233865 Assignment 30 to update hydro-geological studies of the plant backfill to ensure that previous assumptions of tritium migration remain valid as related to the 1995 D'Appolonia Study. Also, more hydrology studies will be conducted as corrective actions to this investigation.

No other input sources were considered during this time period. Because of the lack of monitoring wells, a thorough extent of condition and modeling of the affected area could not be performed. The limited data that was collected supported the RadWaste Effluent line as the only contributor to the tritium concentrations seen in monitoring wells. Migration patterns that were concluded in the D'Appolonia report could have been further

supported with this data.

In 2001, NCR 26566 was initiated to capture concerns following video camera inspections of the plant's Storm Drain Piping. The inspection was performed because of suspected blockage of the Storm Drain lines. The inspection was performed utilizing a video camera mounted to a robotic crawler. The inspection revealed potential degradation of a pipe joint located on the west side of the plant inside the security isolation zone. Concerns over the construction of the storm drain pipe system were discussed particularly related to how the pipes were joined together. The concerns were raised because it was understood that the storm drain piping system was carrying contaminated overflow water from the TB HVAC system to the Storm Drain Collector Basin and that any leakage could enter the groundwater.

The investigation of NCR 26566 revealed that visual inspections were performed on the suspected area of pipe degradation by opening of Storm Drain Manhole #5. This work was performed under Work Order 106771. The pipe joint in that area was confirmed to be completely intact. A separation of three to five inches was observed, but the joint was completely sealed by a concrete collar around the joint. The integrity of the piping was inspected using a screwdriver to probe the circumference of the collar with no discrepancies were noted. It was concluded that the issues examined in the NCR were not potential sources of contaminated water leakage into groundwater.

Passport Attributes Section 4B for NCR 26566 requested an evaluation to determine if the limits for effluents outside those established in 10 CFR 50.72(B)(2)(IV) and 10 CFR 50.73 (A)(2)(VII) had been exceeded that could result in a reportable condition since a potential for leakage existed. The evaluation was performed under NCR 26566 Assignment 5 completed in 2001. The evaluation stated, "inspection results (which showed degradation) and an increasing trend in tritium levels from the environmental well samples located in the vicinity of the pipe joint prompted further investigation". It appeared at that time that the increasing tritium activity trend for the two wells was due to the continued migration of the U/2 RadWaste Effluent Line leak from 1994. The migration appeared to be aided in the few years prior to the investigation by increased hurricanes and torrential rain associated with the storms. The Storm Drain piping was eliminated as a contributor because of the activity of tritium in the TB HVAC was much higher than what was seen in the environmental wells.

Follow up evaluations were performed following completion of NCR 26566 Assignment 5. Assignments 8 and 9 were completed evaluations of the environmental tritium well sample trends following the 2001 and 2002 monitoring programs, respectively. The evaluation of 2001 trends completed under Assignment 8 revealed that another input source of tritium into the environmental wells was suspected. During 2001, tritium trends in Well ESS-2C were elevated. They had begun to stabilize in the latter part of the year. The table below taken from Assignment 8 captures data collected.

Table 1
2001 Comparison of Tritium Data Between Well ESS-2C and 1994 RadWaste Effluent

ESS-2C peak activity	1994 RadWaste peak level	1994 RadWaste peak level (decay correction)
3.26E-03 µCi/ml (3,260,000 pCi/L)	4.09E-03 µCi/ml (4,090,000 pCi/L)	2.76E-03 µCi/ml (2,760,000 pCi/L)

Although the 1994 RadWaste peak level shows a concentration of 4,090,000 pCi/L compared to 3,260,000 pCi/L for Well ESS-2C, a decay correction is required to account for the 12.32 year half life of tritium. The decay correction utilizes the following equation to account for half-life decay:

$$A=A_0e^{-\lambda T}$$

Where: A = current activity
A_0 = initial activity
λ = ln 2 / half life of radionuclide

T = difference of time between current and initial activity

After applying the decay correction, the expected activity in 2001 from the leak identified in 1994 would be 2,760,000 pCi/L. If the plume from the 1994 RadWaste Effluent Line leak was the sole input contributor in 2001, the expected tritium concentration for ESS-2C would be equal to or less than the 2,760,000 pCi/L. Having a higher concentration of tritium, 3,260,000 pCi/L, indicated that another input source was apparent. From 1995 to the evaluation performed in 2001, the well activity levels corresponded to the expected tritium concentrations from the suspected 1994 RadWaste Effluent Line leak. The Storm Drain piping was evaluated to be intact during the 2001 inspection. It was also determined in this 2001 evaluation that the piping was not designed to be leak tight during water solid conditions. The water solid condition occurs when the basin reaches capacity ultimately resulting in a complete fill of the drain piping and additional pressure exerted due to the fluid head from the basin level. Under these conditions, the piping is highly susceptible to leaking. Since the Storm Drain piping is nearer to Well ESS-2C than the RadWaste Effluent Line and water solid conditions have known to exist in the system during periods of heavy rainfall, it was reasonable to conclude that this would be a contributor to the higher than expected tritium concentrations observed during that time. Storm drain piping was used as the transporter of TB HVAC overflow which had tritium concentration averages of approximately 8,000,000 pCi/L. Input from this mechanism was to be mitigated by the incorporation of the Storm Drain Collector Basin Level Management Program. This program was evaluated and captured corrective actions for level control under NCR 46613, Storm Drain Collector Basin Overboard Valves. This program gave guidance for control and operation of the overboard valves for the Storm Drain Collector Basin to prevent flooding of the turbine building and water solid conditions based on the design of the Storm Drain Piping System.

Another evaluation was performed under NCR 26566 Assignment 9 for tritium data collected from environmental monitoring wells in 2002. The evaluation of 2002's data concluded that the tritium concentrations for Wells ESS-2C and ESS-16 continued a decreasing trend that was initially observed in the latter part of 2001. The values obtained from Well ESS-2C had decreased below the decay corrected values from the 1994 RadWaste Effluent Line leak as seen in Table 2.

Table 2
2002 Comparison of Tritium Data Between Well ESS-2C and 1994 RadWaste Effluent

ESS-2C current activity	1994 RadWaste peak level	1994 RadWaste peak level (decay correction)
1.34E-03 µCi/ml (1,340,000 pCi/L)	4.09E-03 µCi/ml (4,090,000 pCi/L)	2.61E-03 µCi/ml (2,610,000 pCi/L)

Along with the decrease, the values obtained for ESS-16 reached the lowest tritium concentrations since sampling began in 1995. Tritium concentrations for Well ESS-2C exceeding the decay corrected value for the 1994 RadWaste Efffluent line leak prompted further investigations into other potential sources in 2001 and actions were put in place to mitigate the input source. The decreasing values were concluded to be recovery from peak values obtained in 2001 prior to the elimination of the additional source and additional dilution obtained from the permeable soil located in the area. The actions implemented as part of the Storm Drain Collector Basin level management program appeared to help mitigate additional tritium inputs into the groundwater. Before the level management program was implemented, three water solid conditions in the Storm Drain Piping were seen in 1999 alone. Since the implementation, only three conditions have been observed in three years. Comparing this improvement to the declining tritium values observed in Wells ESS-2C and ESS-16 helped to validate that Storm Drain Piping is not leak tight during water solid conditions. NCR 26566 was closed following the completion of Assignment 9 since an improving trend was seen in tritium concentrations for Wells ESS-2C and ESS-16 and actions implemented to mitigate other inputs appeared to be effective. Any future degrading trends were to be communicated to supervision and documented through the NCR process.

In June 2006, the Nuclear Energy Institute (NEI) established a task force to improve management of situations involving inadvertent radiological releases that get into the groundwater and to enhance trust and

confidence on the part of local communities, states, the Nuclear Regulatory Commission (NRC), and the public. This was in response to several industry events involving Braidwood, Indian Point, and Salem. The Progress Energy Nuclear Generation Chemistry Peer Group established an initiative across its four nuclear sites to assess equipment that handles radioactive contaminated water and to take the necessary actions to minimize the risk of inadvertent discharge to the environment. The assessments would take place in 2006 and cover equipment that is used to store, process, and convey radioactive contaminated water in and around the plants. The action plan satisfied portions of the industry initiative.

The action plan was to assure compliance with the NEI Initiative on Groundwater Protection and would:

- Provide the opportunity to critically analyze and document the effectiveness of the operational controls and warning systems that is used to prevent, detect, and contain non-permitted releases.
- Document and enhance the understanding of the subsurface structures and groundwater characteristics.

A list of specific actions was developed and tracked via Nuclear Task Management (NTM) 208653.

For NTM 208653 Assignment 4, the industry was asked to respond to a questionnaire from NEI concerning plant specific information on Groundwater tritium. The response was completed on July 28, 2006 and was submitted to NEI and the NRC. An excerpt from BNP response included the following: If applicable, briefly summarize any occurrences of inadvertent releases of radioactive liquids that had the potential to reach groundwater and have been documented in accordance with 10 CFR 50.75(g). The response stated that "The Storm Drain Stabilization Pond contains tritium from the Storm Drain Collector Basin which receives tritium from the overflow of the Turbine Building Airwash system. Well monitoring results confirm that there has been no leakage from the Storm Drain Stabilization Pond to groundwater."

Another action from the Groundwater Initiative included the following, from NTM 208653 Assignment 8, to identify site risks based on plant design including a review of all systems and components that have a credible pathway to groundwater which contain radioisotopes, for examples such as retention ponds or basins. The response from the assignment was that the "Brunswick Plant has committed to implementation of the Groundwater Protection Initiative established by NEI. One of the actions necessary to assess and mitigate groundwater contamination risks at BNP is to identify and categorize sources of radioactivity that have plausible risk to reach groundwater. The identification and ranking of risks performed will be utilized when assessing the need for, and location of additional monitoring methods, including monitoring wells. The Storm Drain Stabilization Pond was identified as a high risk location because it contains high levels of tritium and the bottom is unlined." Storm drains were identified as moderate risk whose tritium levels were dependent upon their inputs and no monitoring methods were in place. The evaluation did not assess the impact for using storm drain piping, which has designed infiltration and ex-filtration rates, to transport tritiated water. Had this been assessed, the system should have been considered high risk.

Assignment 9 from NTM 208653 was issued to update, perform, and/or evaluate the site hydro-geological conditions. The assignment text stated that "this effort should result in an understanding of predominant groundwater gradients based upon current conditions. This effort should also include identification of potential pathways for groundwater migration from on-site locations to off-site locations through the groundwater. Existing hydrology studies (from plant construction), historical environmental studies, and license renewal reports, are all inputs to this action item. This action item should also track updates to the FSAR hydrology study as appropriate." The response from this assignment read that "The 1995 D'appolona Site Assessment report which presents the results of a groundwater study performed at the Brunswick site was reviewed for applicability for 2006. The review was performed by the Environmental Services Section in Progress Energy and Silar Services, Inc. The conclusion of the review is that the 1995 assessment report is valid for 2006. Through interviews with plant personnel, it was determined that the current monitoring well ESS-17 was evaluated as part of this study and was concluded to be properly located to detect migration of tritium through the intermediate sand formation." Another phase of these efforts is being tracked under NCR 233865 Assignment 30 to update hydro-geological studies of the plant backfill to ensure that previous assumptions of tritium migration remain valid as related to the 1995 D'Appolonia Study.

One other key assignment from NTM 298652 was Assignment 11 to evaluate the existing site risks, leakage detection capability (for each at risk system), and the plant history (50.75(g) file review) against the hydro-geological conditions. It was to consider placement of groundwater monitoring wells in the down gradient from

the plant, and sentinel wells close to higher risk systems or components where leak detection capability is limited. The response for the assignment stated, that "it has been determined that there are 2 additional monitoring wells to be installed at/near the stack and intake pumps." To date, these two additional wells have not been installed. There were no new wells proposed for the stabilization pond area. Only high risk systems such as the Storm Drain Stabilization pond were examined. Moderate risk systems such as the Storm Drain piping that transports liquids that eventually route to the Storm Drain Stabilization were not apparent in these reviews.

Based on recent industry operating experience at the Braidwood, Indian Point, and Salem stations where tritium was found in the groundwater, a review of Brunswick's procedure, 0E&RC-3250, GroundWater Monitoring Program, was conducted under NCR 184552, Tritium Ground Water Monitoring Program, Assignment 9. The response revealed that "0E&RC-3250 was reviewed by environmental personnel. Based on the review, the procedure was revised to add sample wells MW-2 and MW-3 to the groundwater monitoring program. Other minor enhancements were incorporated into this revision. Revision 25 of this procedure was issued on 10/16/06. The 10CFR50.57G File was reviewed by an Environmental and Chemistry Specialist under a different action item. No changes were made to 0E&RC-3250 in regards to monitoring the stabilization pond groundwater.

Also in 2006, several electrical manholes located between the Unit 2 Reactor Building and the Auxiliary Surge Tank, were sampled and analyzed for tritium. This event was documented in NCR 204962. Tritium concentrations were detected ranging from 5,900 pCi/L to 1,840,000 pCi/L. Assumptions were made that there was a source of tritium in the groundwater in that area that was leaking into the manholes. Based on the concentrations of tritium indentified, the premise that on site ground water has not moved offsite and that there are no drinking water supplies utilized for onsite groundwater, there is minimal personnel safety or radiological safety impact was made. This discovery was determined not to be a reportable event. The source could not be definitively determined. These manholes were pumped out with no additional in-leakage observed.

In May 2007, detectable levels of tritium were identified in more electrical manholes, MW-5 and MW-6. As part of the investigation, expanded sampling of surrounding surface and groundwater was conducted. As a result, water containing tritium was found in the area on the plant west side of the Storm Drain Stabilization Pond near the tidal marsh at Nancy's Creek. A sample taken from Nancy's Creek did not identify tritium. Additionally, tritium was identified in areas of standing and flowing water outside the dike area of the Storm Drain Stabilization Pond. Some of the water was flowing into the intake canals in two areas, signifying an uncontrolled and unmonitored release of radioactive liquids. Once the water was identified to contain tritium; it was accounted for with liquid release permits. The investigation for this event was captured under NCR 233865.

Current Conditions

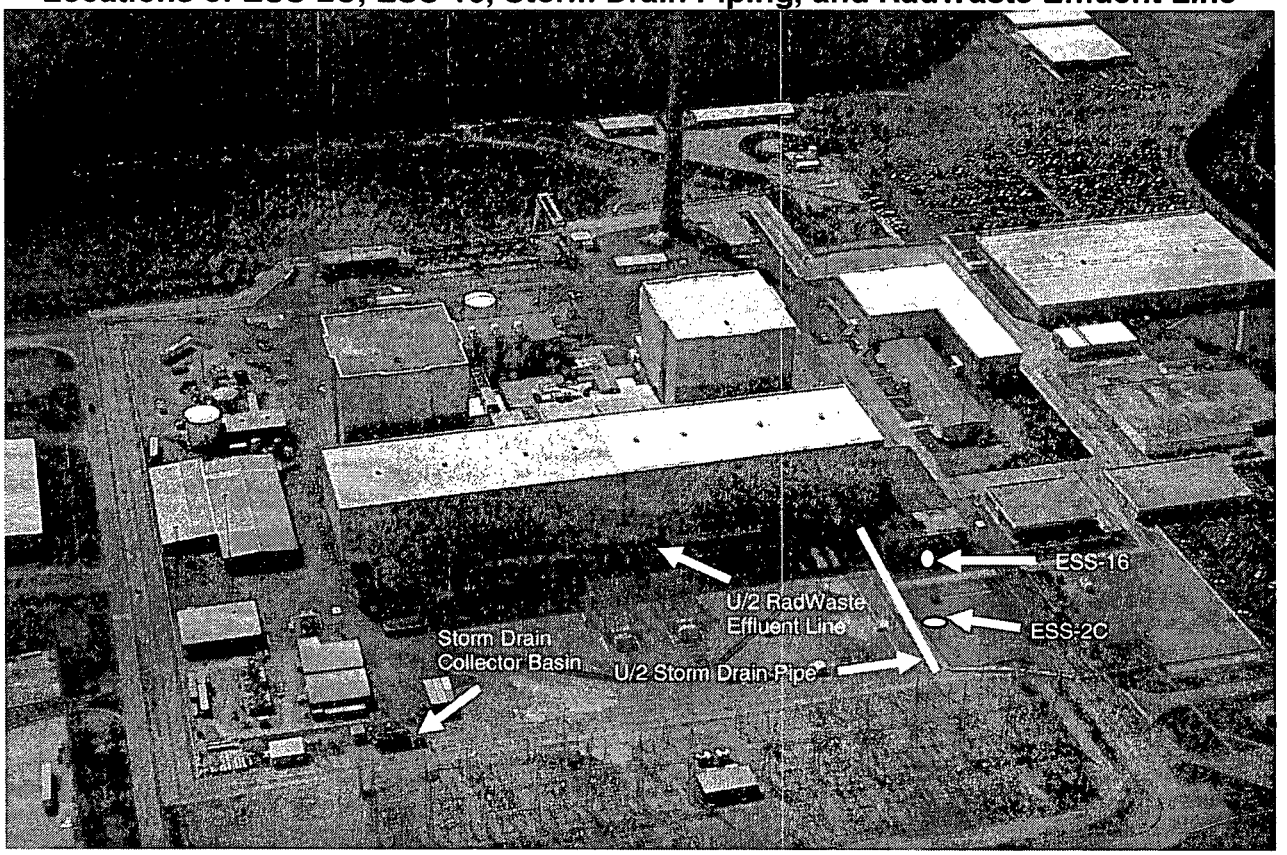
On February 29, 2008, a review of the trend data for environmental monitoring well ESS-2C by Brunswick Environmental and Chemistry personnel indicated that the overall trend for tritium had been increasing. Upon review of other monitoring wells, it was also determined that Well ESS-16 was also showing an increasing trend in tritium concentration. The increasing trends date back to the 2004 and 2005 time frame. The concentration of tritium for Well ESS-2C has increased from approximately 492,600 pCi/L to 1,833,000 pCi/L. The concentration of tritium for Well ESS-16 has increased from approximately 2,230 pCi/L to 64,420 pCi/L. This adverse condition was captured in NCR 268357. Because of known inputs of tritium into the Storm Drain Stabilization pond identified in the Priority 1 investigation for NCR 268357, AirWash overflow to the Storm Drain system was rerouted to RadWaste. After rerouting of the system, short term tritium trends for ESS-2C and ESS-16 have stabilized and have begun to show slight decreases.

Following data collection and analysis, the appropriate reports to offsite agencies, communities, and the public were made voluntarily by the Brunswick Nuclear Plant to communicate a previously unidentified leak. These notifications were made March 7, 2008.

To account for this increasing trend, a multi-discipline team was assembled to determine causes for the increase. Potential input sources in the area were identified that could help determine root cause for the increase. As a result of team discovery, the high potential input sources located in the area are the Storm Drain System piping that runs parallel to Wells ESS-2C and ESS-16 and the historical 1994 U/2 RadWaste

Line leak. Assumptions of other input sources were also made. Examples included potential turbine building leakage or other unidentified leakage. The Storm Drain Piping is located approximately twenty feet east of Well ESS-2C. The location of the 1994 RadWaste Line leak is approximately 240 feet away from ESS-2C. Other monitoring wells in nearby areas, such as ESS-2B and ESS-2D, have not shown an increase of tritium concentrations. This validates statements from the 1995 D'Appolonia report that tritium would be contained in the backfill location, where Wells ESS-2C and ESS-16 were installed based on D'Appolonia suggestions. However, some inconsistencies have been noted within the D'Appolinia report during this investigation that questions its validity and conclusions drawn during the 2006 NEI responses. To further address this concern, Priority 1 NCR 233865 Assignment 30 was initiated to update hydro-geological studies of the plant backfill to ensure that previous assumptions of tritium migration remain valid as related to the 1995 D'Appolonia Study. Actions to evaluate responses to like those given during the 2006 NEI Initiative will be reviewed ensure appropriate measure are in place to prevent inadvertent radiological releases.

Figure 3
Locations of ESS-2C, ESS-16, Storm Drain Piping, and RadWaste Effluent Line



Many assumptions to the definitive input contributor are made because of the lack of monitoring wells in the area. Because the majority of the area is located in the Transformer yard, wells were not permitted to be installed by Site Management following the 1994 RadWaste Effluent Line leak. If monitoring wells were installed, a better means of tracking the tritium plume that was suspected to be created following RadWaste line leak would have been available. This would have also provided another mechanism to determine additional input sources such as Storm Drain Piping or other potential leaks.

Other current known conditions include the preventative maintenance performed each outage on the respective unit's RadWaste Effluent Line. This preventative maintenance includes filling the Effluent Line with approximately fifteen pounds of pressure of air and monitoring for leakage over a period of time. Since the repairs of the U/2 RadWaste Effluent line in 1995, all subsequent leak checks have passed inspections.

From the initial increase seen in the latest increasing tritium trend until June 2007, AirWash basin overflow was routed to the Storm Drain System. Also, during this time period, it should also be noted the plant's units

have operated with active and suppressed fuel leaks. Fuel leaks provide a significant contribution of tritium into the reactor coolant. With a boiling water reactor, the steam from reactor coolant provides the driving mechanism for operation of the turbines. If there are known steam leaks in the turbine building, which is the case for Brunswick, a transport mechanism for steam generated from boiling reactor coolant containing tritium to the turbine building is present. Brunswick's turbine building is maintained at a slightly negative pressure to ensure that unfiltered release of airborne radioactivity does not occur. During the time of the increased trends seen in Wells-2C and ESS-16, the Brunswick plants have utilized a recirculation system for Turbine Building atmosphere. Prior to the exhaust air being drawn into the supply fans, the warm and potentially radioactive air is cooled utilizing two spray coolers. The spray coolers take their suction from a water basin located at the bottom of the pleated filters that provide a mechanical scrubbing of the radioactive air. The spray cools the air that exits the exhaust fans. The cooled, moist air passes through the pleated filters to remove excess heat and contaminates, such as tritium. As more air passes through the filter, spray cooler water is reclaimed in the basin with removed contaminants. The constant recirculation provides a means of buildup of radioactive contaminants in the water. Water overflow, containing tritium, from this basin was routed to the Storm Drain system. However, in June 2007, as a corrective action from NCR 233865 which investigated increased tritium in manholes near the Storm Drain Stabilization pond, the overflow from the AirWash basins were rerouted the plant's RadWaste system to prevent further potential input into the environment.

During the investigation for this NCR, it was also determined that a known potential adverse condition exists for the RadWaste Effluent lines that poses degradation issues. The Effluent Piping was lined in 1995 using material that had a conservative service life expectancy of six to ten years. Using the maximum expected service life expectancy, three years have elapsed past the known service life. When the line was installed, no preventative maintenance was established to replace this liner according to its life expectancy. This presents a run to failure mentality of operation that could potentially introduce contaminated water to enter the groundwater.

Conclusions

All of the input parameters that could be identified by the investigation team were evaluated for cause. To determine cause, a support and refute methodology described in CAP-NGGC-0205 was used to determine the probable and contributing causes. The following failure modes were identified: Storm Drain Piping, Unit 1 and Unit 2 RadWaste Effluent Lines, plume migration following the 1994 U/2 RadWaste Effluent Line leak, and inadequate risk assessments related to the Groundwater monitoring program. To ease tracking of history, the following timeline was created:

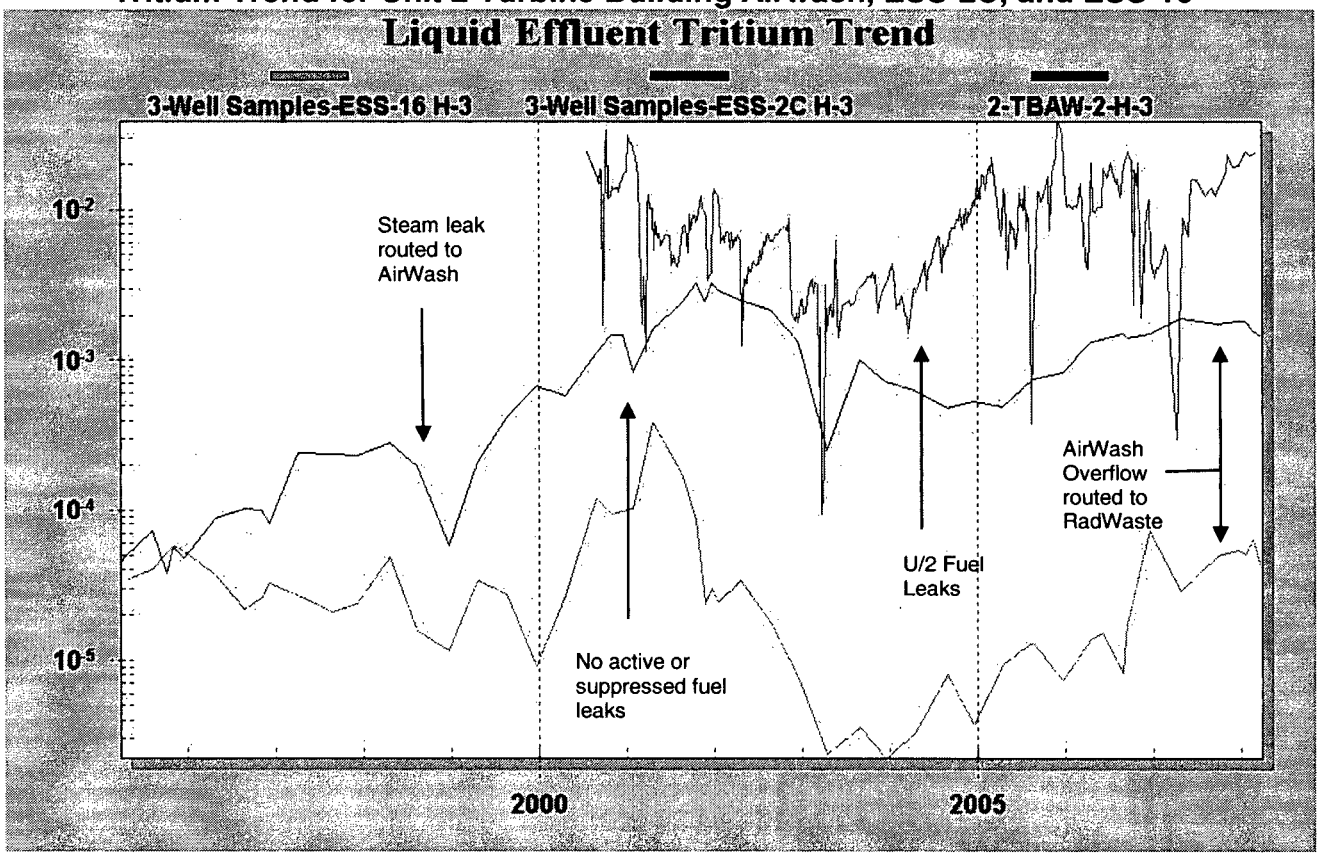
- 1974 – Draft drawing changes were made to the Turbine Building HVAC Overflow routing but were never implemented.
- 1980 – IEB 80-10 issued after inadvertent radiological release for Auxiliary Boiler failure.
- 1987 – Leak assumed and repair efforts completed on RadWaste Effluent Line.
- 1994 – Unit 2 RadWaste Effluent Line failed inspection and was repaired by lining.
- 1995 – Hydrology Study completed by D'Appolonia with Wells ESS-2C and ESS-16 being installed as part of the study.
- 2001 – Inspections to the Storm Drain Piping indicated degradation. Increasing tritium trends were also identified in Wells ESS-2C and ESS-16 which prompted further investigation.
- 2002 – Tritium Data from Well ESS-2C exceeded the expected tritium concentrations, identifying an additional input source.
- 2002 – The Storm Drain level Management program was implemented to prevent water solid conditions.
- 2002-2003 – Declining tritium trends were observed in monitoring wells ESS-2C and ESS-16 confirming actions taking from the Storm Drain Level Management program were effective. NCR 26566 was closed.
- 2004 – 2007 – Tritium Concentrations have increased over this period and were identified in February 2008.

The first input that provided the most credible source of increasing tritium concentrations into Wells ESS-2C and ESS-16 is the Storm Drain System piping. UFSAR, Section 9.3.3.2.3 for Non-contaminated Water Drainage System, describes the drainage collections system as "an underground network of storm sewer piping, non-contaminated building floor drains, and building roof drainage piping. Gravity supplies the motive

force for drainage. Surface drainage, runoff after rains, and neutral non-radioactive wastes are collected by this system. These sources, as well as the Cooling Tower Blow down Discharge and the Makeup Water Treatment System Discharge, feed into the Storm Drainage Basin." This description never mentions potentially radioactive waste such as AirWash Overflow or Rattle Space pump discharge as inputs into the system. The team concluded that Storm Sewer piping is not designed to transport such liquids because the materials used for these systems have designed infiltration and ex-filtration rates. Per the Standard Handbook For Civil Engineers that would have been used during the time of plant construction, infiltration-exfiltration test allowances for storm sewer piping was generally in the range of "250 to 500 gallons per day per inch of diameter per mile of piping." Since storm drain system used at Brunswick was constructed with thirty-six inch diameter concrete sections, this infiltration and ex-filtrations test allowance works out to 9,000 to 18,000 gallons per day per mile of piping.

With the location of the Storm Drain System piping approximately twenty to thirty feet away from Wells ESS-2C and ESS-16, as seen in Figure 3, and the known mobility of tritium, it would be assumed that the tritium trends for these wells would mimic that of the major input source of tritium into the Storm Drain System piping, if the Storm System Piping was the cause. Figure 4 below is a graph of tritium concentrations measured in the Unit 2 Turbine Building AirWash basin, Well ESS-2C, and Well ESS-16.

Figure 4
Tritium Trend for Unit 2 Turbine Building Airwash, ESS-2C, and ESS-16



Tritium analysis for the AirWash system did not begin until late 2000. However, examining the trends shows that Wells ESS-2C and ESS-16 closely follow the trend seen in the Unit 2 Turbine Building AirWash tritium. The rise and falls are also closely related to the fuel leaks faced by the plants. Although the concentration of tritium is much higher in the Unit 2 Turbine Building Airwash, it would be diluted once it reaches non-radioactive liquids transported in the Storm Drain system piping. In June 2007, the AirWash overflow was rerouted to RadWaste. Looking at the annotation on Figure 4 where the overflow lines were rerouted, it does appear that the short term trends have decreased very slightly.

Wells ESS-2C and ESS-16 were originally installed during the 1995 D'Appolonia Groundwater study performed after the RadWaste Effluent line leak to monitor impact from the site. Since these wells contained

tritium, which was known to be a constituent in liquids transported in the Effluent line, this line leak was determined to be the cause of tritium identified in these wells. This determination was also aided by the D'Appolonia report that stated that groundwater would move from the leak towards the backfill. The leak was also located within the backfill. All tritium would be contained in the backfill and groundwater in the backfill would migrate towards the Intake Canal. Wells ESS-2C and ESS-16 are located in the backfill per the D'Appolonia report. However, the Unit 2 RadWaste Effluent line was repaired in 1995 and has passed leak testing performed each refueling outage following those repairs. Since increasing trends have been observed in Wells ESS-2C and ESS-16 since then, it can be assumed the Unit 2 RadWaste Effluent Line leak was not the only input.

Assignment 8 for NCR 26566 was completed to evaluate tritium trends for Wells ESS-2C and ESS-16. As seen in the background section of this report, activity concentrations seen at that time supported an additional input source, which also happened to be the Storm Drain System Piping. The conclusion from that assignment stated that the system was not leak tight during water solid conditions. After reducing water solid conditions, trends for the monitoring wells showed a decrease. This demonstrates a correlation between leaking Storm Drain System piping and increasing tritium concentrations in these wells. It was not evaluated at that time to determine if there was a designed leakage for storm sewer piping and if this piping was being used other than its original intent. Water solid conditions just increased the leakage of the system as a head pressure would be created under that state. Based on design specifications, this piping should be expected to continue leaking during normal conditions.

Other contributing inputs into the Storm Drain piping were reviewed to determine feasibility of causing increased tritium concentrations. The following inputs were ruled out since they contain little to no tritium activity and are considered low inputs into the Storm Drain system: a storm drain located behind the RadWaste Building, Service Air Compressor Condensate, Aux Boiler Blow down, electrical manholes (groundwater infiltration), all power block roof drains, air conditioning condensate, building drains, saltwater drains, Makeup Water Treatment Discharge, and firewater mains. Leakage from the sumps in the turbine building, reactor building, Augmented Off-Gas, Stack, and Stack filter house was discussed as potential inputs into the ground water that could eventually make its way to the system. Groundwater inputs from leaking sumps and associated lines are a low probability due to low volume and little to no activity. For these reasons, they were not considered to be contributors to the increasing tritium trends in Wells ESS-2C and ESS-16, but should be considered as part of the extent of condition for this investigation. Only discharge from Rattle Spaces indicated a moderate amount of tritium activity with an input rate that could not be determined. Rattle spaces will be considered as part of the extent of condition.

Refuting evidence for the Storm Drain system was assessed. As discussed in the background section of this report, inspections were performed on the plant's Storm Drain system piping in 2000 utilizing a camera mounted on a robotic crawler. Some degradation was seen and repaired, but only on the Unit 1 system which is away from the locations of Wells ESS-2C and ESS-16. Unit 2 piping showed no significant damage and showed good integrity. However, in later assignments from the NCR that addressed the finding from these inspections, indications pointed toward Storm Drain system leakage under water solid conditions as a contributor to the increasing tritium trends seen in the monitoring wells.

The following conclusions can be made for the Storm Drain Piping: the design specifications of storm sewer piping that would have been used during the plants' constructions indicate potential for leakage, the trend for a major tritium input into the storm drain system, such as Turbine Building AirWash overflow, mimicked those for the monitoring wells, the near location of the Storm Drain System piping to the wells, as seen in Figure 3, that would allow leakage of a mobile tritium species into the nearby groundwater, and increases in tritium trends for the monitoring well have been seen despite the RadWaste Effluent line passing inspections. From these statements, it can be concluded that the use of storm sewer piping to transport radioactive liquids is outside of its original design and is the most probable causal factor and is a Select Cause for the increasing tritium seen in groundwater collected in Wells ESS-2C and ESS-16. Radioactive inputs into the Storm Drain System must be identified, dispositioned, and discontinued to prevent recurrence of increasing tritium activity in groundwater.

Wells ESS-2C and ESS-16 were installed to assess impact to the site and public following the 1994 RadWaste Effluent Line leak. Since their installation, tritium has been detected in the wells. The detectable tritium was attributed to the RadWaste Effluent Line leak that was known to contain elevated concentrations of tritium. The RadWaste Effluent line receives input from Waste Sample Tank and Floor Drain Sample Tank

releases to the discharge canal. No Floor Drain Sample Tank releases have occurred since 1998. These tanks' inputs have known interfaces with reactor coolant which introduces tritium into the system at large concentrations. The last Waste Sample Tank tritium concentration was recorded at approximately 20,000,000 pCi/L. So, an influence from the RadWaste Effluent line leak on tritium concentrations in Wells ESS-2C and ESS-16 is a valid conclusion based on recommendations from the 1995 D'Appolonia report. The report stated groundwater would move from the leak towards the backfill. Groundwater in the backfill would be contained in the backfill and eventually migrate towards the intake canal. The RadWaste Effluent Line Leak location, Well ESS-2C, and Well ESS-16 are in the backfill area according to the 1995 D'Appolonia report.

Although the RadWaste Effluent Piping was repaired and lined in 1995, it was lined with a material that had a conservative age expectancy of six to ten years. This conservative age expectancy was established under Engineering Evaluation Report (EER) 94-0167. The liner used was a Goodyear Plicord Red Flextra Hose. This liner is three years past expected life and currently no preventative maintenance schedules exists to replace the liner at a set frequency. Based on the shelf life of this liner, degradation could be expected which is a potential for leaching of radioactive liquids into the groundwater. This line was suspected to be leaking back in 1987 so it can be assumed that this line leaked tritium into the groundwater prior to 1987. It is also reasonable to assume that the line was susceptible for leaking following the 1987 repair to 1994 when the line was repaired and lined. No inspection data was available to discount these assumptions.

With this potential for leakage based on degradation, it is also important to note that liquid effluent releases, which include WST's, have also increased during the time period covering the increasing tritium trends in Wells ESS-2C and ESS-16. In 2004, 72,416 gallons of liquid effluents were released. This value saw a significant increase to 574,697 gallons, 541,270 gallons, and 1,710,933 gallons in 2005, 2006, and 2007, respectively. Per the D'Appolonia Report, a leak from the RadWaste Effluent that is inside the plant's backfill would migrate and be contained in the backfill. Since the location of Wells ESS-2C and ESS-16 are located in the backfill according to the D'Appolina report, it is reasonable to conclude the elevated volume of releases with high tritium activities could account for increases in tritium for these wells.

The refuting evidence for the RadWaste Effluent lines contributing to the increasing tritium concentrations in the monitoring wells is the fact that the increasing trends have been observed although the RadWaste Effluent lines have passed their leak inspections since their lining in 1995. Each inspection occurs during the refueling outages for each respective unit. However, the liner used for repair has been in service past its conservative service life for approximately three years. There is some potential that degradation exists. Currently, the leak test is performed by pressurizing the line to 15 pounds with air and monitoring the pressure of a period of time. If the pressure remains stable, the preventative maintenance passes inspection. This leak test is being enhanced to provide clearer instructions and acceptance criteria. This enhanced testing will not be performed on the Unit 2 RadWaste Effluent line until its upcoming refueling outage scheduled for March 2009. Comparing activity concentrations as seen in Table 3, contributions from the 1994 RadWaste Effluent line leak still correspond well with Well ESS-2C, indicating that it is still a possible source.

Table 3
2008 Comparison of Tritium Data Between Well ESS-2C and 1994 RadWaste Effluent

ESS-2C current activity	1994 RadWaste peak level	1994 RadWaste peak level (decay correction)
1.46E-03 µCi/ml (1,460,000 pCi/L)	4.09E-03 µCi/ml (4,090,000 pCi/L)	1.86E-03 µCi/ml (1,860,000 pCi/L)

Although the probability of the RadWaste Effluent line contributing to the increase in tritium seen in Wells ESS-2C and ESS-16 appears low, a probability still exists. Previous failures of the RadWaste Effluent line have resulted in known tritium leakage into the plant's backfill. However, a run to failure mentality currently exists with the liner that was used for repair of the RadWaste Effluent lines and conducting business in this

fashion introduces a potential contributing factor for increasing tritium concentrations within the plant backfill. Risk potential and consequences have not been fully evaluated with not performing preventative maintenance to replace the lining or replacing the RadWaste Effluent piping has been identified as a Select Cause.

The definitive contributions from the two highly probable sources, Storm Drain System Piping and the RadWaste Effluent line, could not be fully evaluated because of the lack of monitoring wells located in this area. Following the repair of the RadWaste Effluent line, an assessment and report was completed by D'Appolonia in 1995. Monitoring wells were installed to help evaluate the impact to the plant and public. However, due to the location of the RadWaste Effluent Line which is in the Transformer area of the plant, monitoring wells were not approved for installation by Site Management per interviews with the Progress Energy Geologist who was involved with the project. This prevented effective modeling of the affected area and could have led to an earlier discovery of tritium inputs into the groundwater prior to NEI initiatives and heightened awareness of tritium from other industry experiences. The RadWaste Effluent line leak potentially masked other input sources since the only monitoring wells that were installed in the backfill area coincided with data that should have been expected from the RadWaste Effluent Line. It is difficult to tell if the contributor to the increased tritium in the monitoring wells is a combination of sources or solely from one. This lack of data prevented conclusions and actions to be completed at a much earlier time frame. This demonstrates that the groundwater monitoring that was established at Brunswick during this time was considered acceptable with future environmental risks not adequately understood. This is the identified root cause for the increasing tritium trends observed in Wells ESS-2C and ESS-16. This root cause is further supported by other factors such as the lack of environmentally responsible responses to NCR's, NEI initiatives, ANI recommendations, and proposed changes like the rerouting of the TB HVAC proposed in 1974.

Reference Material Used for Investigation

- Priority 1 NCR 233865 – Tritium Discovered in Manholes Near the Storm Drain Stabilization Pond
- NCR 26566 – Degradation Observed in Storm Drain Piping
- NCR 204962 – Tritium Discovered in Manholes Near Auxiliary Surge Tank
- NCR 46613 – Storm Drain Collector Basin Overboard Valves
- NCR 184552 – Tritium Ground Water Monitoring Program
- NCR 272173 – Tritium in 1A North Circulating Water Intake Line
- Adverse Condition Report (ACR) 94-00626 – Unit 2 RadWaste Effluent Line Leak
- UFSAR Section 9.3.3.2.3 – Non-contaminated Water Drainage System
- NTM 208653 – Response to 2006 Nuclear Energy Institute Groundwater Monitoring Initiative
- CAP-NGGC-0205 – Significant Adverse Condition Investigations
- 0E&RC-3250 – Groundwater Monitoring Program
- 0E&RC-0037 – Radiation Protection Controls for Work in Tritium Areas
- Response to American Nuclear Insurers (ANI) Recommendation LR97-06
- 2006 Nuclear Energy Institute Groundwater Monitoring Initiative
- Office of Inspections and Enforcement Bulletin 80-10
- Site Assessment Report – Unit 2 RadWaste Effluent Line prepared by D'Appolonia
- Engineering Evaluation Report (EER) 94-0167
- OE 24237 – Low Levels of Tritium Detected (Palo Verde Unit 3)

4. Previous Operating Experience (Internal and External)

Internal OE

Internal OE was assessed by review of applicable documentation used during the preparation of this investigation report. Summaries of these reviews are provided during discussions in the background section of this document.

The primary OE that will be discussed is the event of tritium discovered in manholes that was caused by leaching from the Storm Drain Stabilization pond. The event is very similar to this event because both causes conclude that inputs from the TB HVAC blow down into the Storm Drain Systems caused elevated tritium concentrations and a lack of programmatic oversight and understanding was present. Organizational factors

such as the lack of programmatic oversight were also demonstrated by the lack of aggressive responses to NCR's, NEI initiatives, ANI recommendations, and proposed changes like the drawing changes for the TB HVAC proposed in 1974. Detailed history and conclusions to these responses are documented in the background section of this report.

It cannot be concluded if the actions implemented from the investigation that was performed under NCR 233865 were effective as enough time has not elapsed to implement all actions or evaluate the benefits from completed actions. A good example is an action implemented to reroute the TB HVAC blow down to RadWaste vice the Storm Drain System. Since the time of securing this system's overflow, it appears as though the tritium concentrations in Wells ESS-2C and ESS-16 have stabilized and slightly dropped. However, these are short term trends and any reasonable conclusion cannot be made at this time. Any lessons learned will be documented in the Corrective Action Table.

Actions from Adverse Condition Report (ACR) 94-00626, Unit 2 RadWaste Effluent Line Leak were examined to determine effectiveness of the actions. The focus of the ACR was primarily on potential leaks from the RadWaste System and from systems with known interfaces such as the Condensate Storage Tanks. No discussion or evaluation on the plant's Storm Drain Piping was conducted.

External OE

There have been a number of events in the industry in recent years involving tritium leakage from plant systems into groundwater. Documentation has been reviewed with the incident from Braidwood drawing similarities and applicability with Brunswick. This was also discussed in NCR 233865. Any lessons learned will be captured in the Corrective Action Table.

Several unmonitored on-site releases of radioactive contaminated water into the environment have also occurred within the Nuclear Generation industry. The three well documented events occurred at the Braidwood, Indian Point, and Salem stations. To some extent, the releases have gone undetected preventing prompt initiation of corrective actions which could have reduced the magnitude and severity of the impacts. Comparable to Brunswick, none of the releases seen at these stations have shown adverse effects to the health and safety of the public or the station employees. Upon discovery and the heightened awareness to the situation, expanded monitoring through installation of new test wells was conducted to better define the scope and magnitude of detectable tritium.

In June 2006, the Nuclear Energy Institute (NEI) established a task force to improve management of situations involving inadvertent radiological releases that get into the groundwater and to enhance trust and confidence on the part of local communities, states, the Nuclear Regulatory Commission (NRC), and the public. This was in response to the industry events involving Braidwood, Indian Point, and Salem. The Progress Energy Nuclear Generation Chemistry Peer Group established an initiative across its four nuclear sites to assess equipment that handles radioactive contaminated water and to take the necessary actions to minimize the risk of inadvertent discharge to the environment. The assessments took place in 2006 and covered equipment that is used to store, process, and convey radioactive contaminated water in and around the plants. The action plan satisfied portions of the industry initiative.

Washout is another area of concern for tritium input into the site's groundwater. Washout occurs when contaminants in the air are "washed" to the ground during periods of rain. This mechanism is typically associated during accident scenarios, but the same holds true for low level contamination in the atmosphere. OE from Palo Verde concluded that the source of tritium discovered in the site's Radiological Controlled Area was due to past operational practice and events. The most probable cause was washout that occurred during the past when the plant operated during rain events, wash down of roofs, or washout from rain during times when tritium in condensation from the ventilation system was present. Brunswick currently uses a recirculation system to contain the Turbine Building Atmosphere, but a Once Through Modification is in testing for permanent installation. This is a potential washout concern area that should be evaluated along with other likely sources. An assignment to evaluate washout as a potential source of input of tritium into groundwater will be created in the Corrective Action Table. Implementation of any recommendations from the evaluation should be assigned as follow up or additional actions.

5. Extent of Cause

The Brunswick site has a wide array of manholes, sumps, underground piping, and basins that could potentially be susceptible to some of the causal factors that have been identified, particularly the inadequacy of a site wide program to manage current tritium known to be contained in the site's groundwater and to manage potential future inputs from plant leakage. Enhancement items will be assigned to establish a program manager to provide oversight to the sites initiative to manage current tritium that has been identified in the groundwater but to also manage potential input sources related to plant leakage.

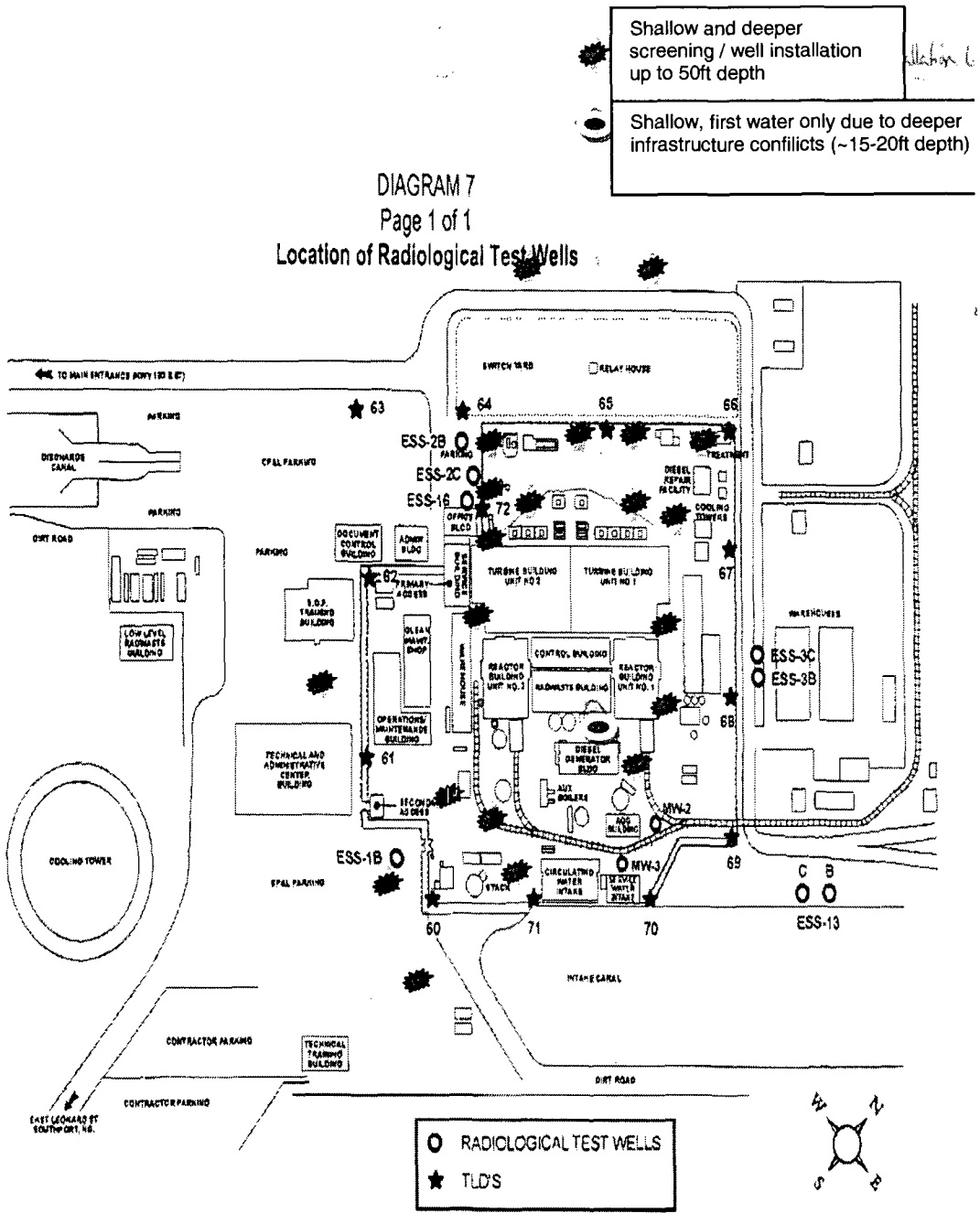
Other casual factors were specifically related to a system. Corrections should not be implemented solely for Brunswick 2, but implemented to both units. No other products, processes, components, or systems could be deemed as potentially susceptible to the casual factors listed in this report.

6. Extent of Condition

The Brunswick site has a wide array of manholes, sumps, underground piping, and basins that could potentially be susceptible to some of the causal factors that have been identified, particularly the inadequacy of a site wide program to manage current tritium known to be contained in the site's groundwater and to manage potential future inputs from plant leakage.

Because tritium has been identified at various locations on the site such as leach sites from the Storm Drain Stabilization Pond and electrical manholes, monitoring well locations have been evaluated and established around the perimeter of the plant. New wells will be required to effectively monitor the site to reduce risk of the casual factor related to not having the right monitoring wells to fully understand the plant impact related to tritium leakage into the groundwater. Corrective actions will be assigned to install new monitoring wells across the site to assist with programmatic oversight. Currently, progress towards installing new wells is being made. Walk downs of the site have been performed and proposed locations have been made. These proposed locations can be seen in Figure 5.

Figure 5
Proposed Locations of Temporary Wells for BNP



NOTE: Well ESS-17 is located near the Biology Lab.

After installation of new wells, a site-wide modeling will be completed to map tritium inputs and migration to help mitigate future impacts. Corrective actions will be assigned to sample and analyze any manhole, basin, and well on site that is readily accessible to assess the magnitude and severity of the plant's tritium impact.

The Storm Drain Collector Basin is susceptible to failure similar to the Storm Drain piping since it is constructed of cement without adequate lining. Potential exists from contaminated water leaching through the walls of the basin and into the ground water. A corrective action will be assigned to line the basin and develop standards for operation and maintenance of the plant's Storm Drain Collector Basin.

Other sumps located within the plant should be evaluated to determine their extent of condition and to make repairs or improvements as necessary to prevent potentially contaminated liquids from reaching the groundwater. Actions will be assigned to address this concern.

Viable input sources into the Storm Drain System will be evaluated to determine if risk is present by their continued input. For this investigation, many inputs were determined as non-contributors for the increase seen in the monitoring wells, but potential contributions for input into groundwater may still be present.

One particularly source, Rattle Spaces, is known to contain a moderate level of tritium activity. Recent sample results have shown 20,000 to 100,000 pCi/L of tritium activity. The input liquid source into the Rattle Spaces is groundwater. Groundwater will make its way into the Rattle Space and is discharged in to the Storm Drain System. Based on conclusions from this investigation, a potential is present for these contents to leach back into groundwater. The represents a mode of recycling for tritium already contained in the groundwater rather than providing a new source of tritium into the groundwater. Corrective actions will be assigned to identify and discontinue additional radioactive input sources into the Storm Drain System.

NCR 233865 for tritium leaching from the Storm Drain Stabilization pond did not adequately address the extent of condition related to identifying and securing sources and did not take into account the broadness of the plant's impact with tritium release. Corrective actions will be assigned to establish a project manager to provide oversight to the site's initiative to manage current tritium that has been identified in the groundwater but to also manage potential input sources related to plant leakage.

It should be noted that Corrective Actions from NCR 233865 will address some extent of condition applicable to this investigation. Areas outside the protected area were reviewed as potential pathways for tritium. The Technical Training Building, Turbine Rotor Storage area, Cooling Tower area, and Clean Trash area did not pose a potential as a new source for a tritium pathway. The Outside Sewage Treatment Plant is routinely monitored for tritium with none detected. This does not pose a potential pathway. The NPDES outfalls 007 and 008 have been monitored and have shown detectable tritium. The causes were investigated under NCR's 252613 and 252608. Causes for both NCR's adverse conditions and inappropriate acts were listed as indeterminate with additional sampling and monitoring required.

Since steam leaks in the Turbine Building have been identified as a major contributor to tritium to the Turbine Building atmosphere, they should be identified and discontinued to mitigate tritium input. Programs are in place to evaluate and prioritize steam leaks as they are identified. Aggressive efforts, such as Foreign Material Exclusion and changing fuel vendors who have a more robust debris filter, are already in place to minimize fuel leaks which in turn decrease tritium inventory. Tritium concentrations in the vessel are impacted by boron concentrations that could be elevated due to leaking control rod blades. Efforts are made during the fuel cycle to identify potentially leaking control rod blades for replacement in the subsequent refueling outage.

During the investigation period for this NCR, a walk down was performed for the Unit 1 Circulating Water piping. Per NCR 272173 for Tritium in 1A North Circulating Water Intake Line, a through wall leak was identified in the Unit 1 Circulating Water intake piping and contained tritium in the groundwater leaking into the pipe. The tritium concentration was found to be 11,870 pCi/L. This location of leaking piping is within the location of tritiated groundwater's movement from the backfill to the intake canal as described in the D'Appolonia report. It could be expected that groundwater inleakage into failed underground piping systems or designed systems such as Rattle Spaces in these areas, may contain tritium. This movement will be further confirmed during corrective actions to model the groundwater movement in the protected with installation of new wells and follow up hydrology studies.

7. Safety Significance

Although tritium concentration increases have been observed in monitoring wells ESS-2C and ESS-16, tritium concentrations have been confirmed before in these locations and since the time of their installation in 1995. The increase in tritium indicates that sources have not been isolated to prevent release of tritium to the groundwater in the areas of these wells and that a previously unidentified leak is present. Sample results from these wells and other wells onsite indicated that all detectable tritium activity has been confined to company property and have not impacted groundwater that is used for drinking according to hydrology studies performed to date. Based on conclusions made in the D'Appolonia report, these wells are contained in the backfill and that any tritium located in the backfill will be contained. These statements from the D'Appolonia report will be confirmed during post investigation actions such as site wide hydrology assessment following the installation of new wells.

Access to the wells is restricted as they are capped with covers that require force to remove. However, an evaluation will need to be made to the radiological concerns around these two wells to prevent any unnecessary contamination to site personnel. An action will be created in the Corrective Action Table to evaluate these radiological concerns and to make necessary postings.

This incident does not pose any threat to site safety related equipment. There has been no adverse offsite impact resulting from this condition. Safety to the public or site personnel has not been jeopardized. Plant procedures such as 0E&RC-0037, Radiation Protection Controls for Work in Tritium Areas, are in place to further insure the safety to plant personnel performing work in affected areas.

8. Summary of Results

The following conclusions can be made for the Storm Drain Piping: the design specifications of storm sewer piping that would have been used during the plants' constructions indicate potential for leakage, the trend for a major tritium input into the storm drain system, such as Turbine Building AirWash overflow, mimicked those for the monitoring wells, the near location of the Storm Drain System piping to the wells, as seen in Figure 3, that would allow leakage of a mobile tritium species into the nearby groundwater, and increases in tritium trends for the monitoring well have been seen despite the RadWaste Effluent line passing inspections. From these statements, it can be concluded that the use of storm sewer piping to transport radioactive liquids is outside of its original design and is the most probable causal factor and is a Select Cause for the increasing tritium seen from groundwater collected in Wells ESS-2C and ESS-16. Radioactive inputs into the Storm Drain System must be identified, dispositioned, and discontinued to prevent recurrence of increasing tritium activity in groundwater.

Although the probability of the RadWaste Effluent line contributing to the increase in tritium seen in Wells ESS-2C and ESS-16 appears low, a probability still exists. Previous failures of the RadWaste Effluent line have resulted in known tritium leakage into the plant's backfill. However, a run to failure mentality currently exists with the liner that was used for repair of the RadWaste Effluent lines and conducting business in this fashion introduces a potential contributing factor for increasing tritium concentrations within the plant backfill. Risk potential and consequences have not been fully evaluated with not performing preventative maintenance to replace the lining or replacing the RadWaste Effluent piping has been identified as a Select Cause.

The definitive contributions from the two highly probable sources, Storm Drain System Piping and the RadWaste Effluent line, could not be fully evaluated because of the lack of monitoring wells located in this area. Following the repair of the RadWaste Effluent line, an assessment and report was completed by D'Appolonia in 1995. Monitoring wells were installed to help evaluate the impact to the plant and public. However, due to the location of the RadWaste Effluent Line which is in the Transformer area of the plant, monitoring wells were not approved for installation by Site Management per interviews with the Progress Energy Geologist who was involved with the project. This prevented effective modeling of the affected area and could have led to an earlier discovery of tritium inputs into the groundwater prior to NEI initiatives and

heightened awareness of tritium from other industry experiences. The RadWaste Effluent line leak potentially masked other input sources since the only monitoring wells that were installed in the backfill area coincided with data that should have been expected from the RadWaste Effluent Line. It is difficult to tell if the contributor to the increased tritium in the monitoring wells is a combination of sources or solely from one. This lack of data prevented conclusions and actions to be completed at a much earlier time frame. The root cause for increasing tritium trends observed in Wells ESS-2C and ESS-16 has been identified as groundwater monitoring that was established at Brunswick during its history was considered acceptable with future environmental risks not adequately understood. This root cause is further supported by other factors such as the lack of aggressive responses to NCR's, NEI initiatives, ANI recommendations, and proposed changes like the rerouting of the TB HVAC proposed in 1974.

9. Inappropriate Acts / Equipment Malfunctions/Causal Factors/Corrective Action Plan

- Complete the below table to identify the required information
- Place information in the non-shaded areas only. This is to help align the cause for each Inappropriate Act and to ensure that each Cause is linked to and addressed with a Corrective Action.
- Clearly describe each causal factor as to how it applies to the investigated event / condition. (Do not just cut and paste the cause definition from CAP-NGGC-0206). Designate each causal factor as "Root" or "Contributing"
- The "Code" column is used to identify the Cause Code (CAP-NGGC-0206 Attachment 2)
- The "ORG" column is used to identify the organization responsible for the Inappropriate act.
- Designate the type of action (CAPR, CORR or ENHN). Reference attachment 15 for guidance as needed.
- For completed or interim actions, provide appropriate completion documentation or ensure that the investigation results contain adequate detail to ensure traceability, for example; Work Order "ABC" was completed and approved on mm/dd/yy, Engineering Change Request "XYZ" was completed in the field on mm/dd/yy, or Material Evaluation was completed and approved on mm/dd/yy.

ATTACHMENT 16
Sheet 3 of 3
Significant Adverse Condition Investigation Report
Form CAP-NGGC-0205-16-6

Corrective Action Plan

	DESCRIPTION	CAUSE	CODE	ORG	CORRECTIVE ACTION	ASSIGNMENT TYPE*	ASSIGNEE/ CONCURRENCE	DUE OR COMPLETION DATE**
ADVERSE CONDITION	Increasing tritium concentrations were observed in environmental monitoring wells ESS-2C and ESS-16 that indicate a previously unidentified leak into groundwater	N/A	N/A	N/A	Increase sampling and monitoring of Wells ESS-2C and ESS-16 and incorporate changed frequency in 0E&RC-3250	CORR	Marty McGowan / Jerry Johnson	Complete 1/17/08
					Evaluate radiological conditions at Wells ESS-2C and ESS-16 and surrounding area and implement posting and labeling if required	CORR	John Vincelli / Jeff Ferguson	Due 5/23/08
					The CAPR's listed to correct cause code C6 will also aid in correcting the increased tritium observed in the environmental monitoring wells.			
I/A or EQ Malfunction	Contaminated liquids containing tritium have possibly leached from the Storm Drain piping and entered the groundwater	The risks and consequences of utilizing Storm Drain Piping other than its original design were not well understood (Select Cause)	C6	BESS	Discontinue tritium source from the TB HVAC system to Storm Drain system and route to RadWaste	CAPR	Pete Dorosko / Bill Stackhouse	Complete 6/6/07
					Identify potential radioactive inputs other than washout from rainwater and groundwater into the Storm Drain Piping	CORR	Kenneth Welch / Barry Davis	Due 6/27/08
					Disposition and discontinue identified radioactive inputs into the Storm Drain System	CAPR	John Becker / Ben Waldrep	Due 3/25/10* (potential for outage related work)

	DESCRIPTION	CAUSE	CODE	ORG	CORRECTIVE ACTION	ASSIGNMENT TYPE*	ASSIGNEE/ CONCURRENCE	DUE OR COMPLETION DATE**
I/A or EQ Malfunction	Contaminated liquid transported within the RadWaste Effluent line could potentially leach into the groundwater	The risk potential and consequences of not performing preventative maintenance to replace the liner were not fully understood or evaluated. (select cause)	J4a	BESS	Replace piping or pipe liner for the U/1 RadWaste Effluent Lines and develop standards for operation and maintenance.	CAPR	John Becker / Ben Waldrep	Due 5/25/10* (B118R1)
					Replace piping or pipe liner for the U/2 RadWaste Effluent Lines and develop standards for operation and maintenance.	CAPR	John Becker / Ben Waldrep	Due 5/25/09* (B219R1)
	Efforts were not approved, implemented, or thoroughly evaluated in the past to reduce potential of leakage of tritium in the groundwater.	Groundwater monitoring was considered acceptable based on risk factors that were evaluated and understood (Root Cause)	D3	E&RC	Install monitoring wells within the Protected Area that will adequately model and assess tritium migration	CAPR	Mike Millinor/ Jerry Johnson	Due 10/1/08*
					Conduct hydrology study of Protected area and evaluate contracted hydrologist recommendations with site management. Issue actions accordingly under NCR 268357.	CAPR	Mike Millinor/ Jerry Johnson	Due 12/19/08*
		Tracking and trending expectations were not documented or proceduralized to establish appropriated commitment (contributing cause)	D3	E&RC	Install new monitoring wells within the Owner Controlled Area to adequately model and assess tritium migration from the plant	CAPR	Mike Millinor/ Jerry Johnson	Due 3/27/09*
					Conduct hydrology study of Owner Controlled area and evaluate contracted hydrologist recommendations with site management. Issue actions accordingly under NCR 268357.	CAPR	Mike Millinor/ Jerry Johnson	Due 5/29/09*
					Evaluate assignments and responses to past recommendations and initiatives from outside	CORR	Mike Millinor / Jerry Johnson	Due 7/25/08

	DESCRIPTION	CAUSE	CODE	ORG	CORRECTIVE ACTION	ASSIGNMENT TYPE*	ASSIGNEE/ CONCURRENCE	DUE OR COMPLETION DATE**
					organizations and issue necessary corrective actions to ensure measures are in place to manage inadvertent radiological releases			
					Facilitate Inspection of sumps located within the plant to determine the extent of condition	CORR	Levy Grady / Kim Gerald	Due 3/25/09*
					Complete repairs or improvements following sump inspections to prevent potentially contaminated liquids from reaching the groundwater	CORR	John Becker / Ben Waldrep	Due 6/25/09*
					Complete sampling profile of Storm Drain Catch Basins, Rattle Spaces, currently installed wells, and manholes across the site to characterize tritium	CORR	Mike Millinor / Jerry Johnson	Due 3/27/09*
					Line the Storm Drain Collector basin to prevent leaching of radioactive contents into groundwater and develop standards for maintenance and operations	CORR	John Becker / Ben Waldrep	Due 5/31/09*
					Conduct an independent review of program effectiveness and decisions following completion of hydrology studies	CORR	Mike Millinor / Jerry Johnson	Due 3/1/09*
					Evaluate BNP Steam Leak Mitigation programs and procedures and revise as necessary to ensure tritium	CORR	Alicia Baker / Jerry Johnson	Due 7/18/08

	DESCRIPTION	CAUSE	CODE	ORG	CORRECTIVE ACTION	ASSIGNMENT TYPE*	ASSIGNEE/ CONCURRENCE	DUE OR COMPLETION DATE**
					impacts are evaluated in the decision process			
					Establish an Environmental and Chemistry tracking and trending program that will define goals and responsibilities to ensure timely response to emerging trends	CORR	Jeremie Varnam / Jerry Johnson	Due 12/31/08*
					Repair through wall leak on U/1 Circulating Water Piping during B117R1	CORR	Robert Herzog / Richard Bissett	Complete (WO 1320501) 4/22/08
OTHER	N/A	N/A	N/A	N/A	Validate and Update FSAR based on completed hydrology study	ENHN	Mike Millinor / Jerry Johnson	Due 7/31/09
					Verify drawings to ensure no other underground lines other than Storm Drain System piping and the RadWaste Effluent line could potentially lead to tritium leakage into groundwater	ENHN	Martin Souther / Bill Stackhouse	Complete 3/25/08
					Evaluate potential for washout as a contributor of radiological inputs into the groundwater	ENHN	Mike Millinor / Jerry Johnson	Due 4/21/09
					Establish a Program Manger to oversee recovery of the monitoring wells and manage tritium oversight for BNP	ENHN	Jerry Johnson / Jeff Ferguson	Complete 3/25/08
					After completion of all items for NCR 268357, vault NCR 268357 as part of the plant's decommissioning records.	GNRL	Nancy Holley / Jeff Ferguson	Due 6/30/10

	DESCRIPTION	CAUSE	CODE	ORG	CORRECTIVE ACTION	ASSIGNMENT TYPE*	ASSIGNEE/ CONCURRENCE	DUE OR COMPLETION DATE**
					Conduct Formal Benchmark of Plants impacted by Tritium to evaluate effectiveness of BNP Tritium programs	ENHN	Mike Millinor / Jerry Johnson	Due 12/31/09
OTHER	N/A	N/A	N/A	N/A	Conduct an Effectiveness Review	EREV	Jeremie Varnam / Jerry Johnson	Due 8/21/09

* Designate which assignments are Long Term Corrective Action (non-outage related LTCA requires approval by DSO – Manager PE&RAS for corporate).

**Provide justification for corrective actions to prevent recurrence (CAPR) with initial due date that exceeds 90 days and for corrective actions (CORR) with initial due date that exceeds 120 days.

9. Effectiveness Review Criteria: An Effectiveness Review will be completed to measure the success for the Corrective Action plan that is presented in this investigation report. The following criteria will be used to ensure that desired results have been achieved:

- Based on actions completed to repair and replace underground piping that was suspected to be leaking and discontinuing radioactive inputs into Storm Drain Piping, determine if desired results have been obtained in monitoring wells ESS-2C and ESS-16. Desired results would be a noticeable declining trend in tritium concentrations.
- Based on actions completed, determine the overall effectiveness of tritium management that has been implemented. This effectiveness can be determined by timely completion of evaluations assigned from this report and that all necessary actions to control current tritium existing in the ground water and actions have been implemented to mitigate further leakage of tritium into the groundwater.
- Based on the repairs implemented to secure potential radioactive inputs into groundwater, ensure that appropriate operational and maintenance programs exists to ensure long term reliability and integrity.
- After installation of temporary wells and selection of permanent wells, determine if the appropriate selections have been made to adequately model and understand the movement and impact of tritium seen at Brunswick.

10. Basis, If Effectiveness Review is waived: An Effectiveness Review will be completed using the Effectiveness Review Criteria listed in Section 9. An action has been assigned in the Corrective Action Table.

11. PNSC/CSERB Review Required? YES ☐ NO ☒

This investigation will be reviewed by the Corrective Action Review Board (CARB).