Remedial Investigation Report

PSEG Nuclear, LLC
Salem Generating Station
Hancock's Bridge, New Jersey

March 2004

PREPARED FOR

PSEG Services Corporation
80 Park Plaza
Newark, NJ 07102

ARCADIS

Infrastructure, buildings, environment, communications

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PSEG Nuclear LLC
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Bradley D. Pierce
Staff Scientist

Peter N. Milionis, PG
Project Manager

Scott T. Potter, PhD, PE
Principal Engineer

Prepared for:
PSEG Services Corporation
80 Park Plaza
Newark, NJ 07102

Prepared by:
ARCADIS G&M, Inc.
6 Terry Drive, Suite 300
Newtown, Pennsylvania 18940
Tel 267.685.1800
Fax 267.685.1801

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Executive Summary

ARCADIS, Inc. (ARCADIS), on behalf of PSEG Services Corporation ("PSEG SC"), has prepared this Remedial Investigation Report to document the findings of a remedial investigation conducted at the PSEG Nuclear, LLC Salem Generating Station (the "Station") located on Artificial Island in Lower Alloways Creek Township, Salem County, New Jersey. The groundwater investigation was conducted in accordance with the scope of work defined in the Remedial Investigation Work Plan ("June 2003 RIWP") and the Initial Groundwater Investigation Report and Remedial Investigation Work Plan Addendum ("RIWP Addendum") that were submitted to the New Jersey Department of Environmental Protection ("NJDEP") in June 2003 and January 2004, respectively. The scope of work outlined in these documents was designed to investigate the discovery of tritium in the shallow, water-bearing unit adjacent to Unit 1 of the Salem Generating Station.

The remedial investigation was initiated in September 2002 following the detection of low-level radioactive contaminants on the shoes of Station technicians. Initial investigations indicated that the source of the low-level radioactive contaminants was water seeping through small cracks in the 78-foot Mechanical Penetration Room of the Unit 1 Auxiliary Building. Further investigation revealed a second leak at the 92-foot elevation of the Unit 1 Spent Fuel Pool cooling line, adjacent to the pipe penetration through the concrete wall. Analytical results of water samples collected from the leaks indicated that the water had characteristics of Spent Fuel Pool water and that a leak from the Spent Fuel Pool system had likely occurred.

The Salem Generating Station Unit 1 Spent Fuel Pool is lined with stainless steel. Behind the stainless steel liner are liner drains (commonly referred to as "telltale drains") that are used as a combined leak monitoring, collection, and drainage mechanism. On January 31, 2003, a fiber optic examination of two of the telltale drains indicated that mineral deposits had formed a blockage in them. The blockage obstructed the flow of water in these drains resulting in the accumulation of Spent Fuel Pool water, which likely migrated along the paths of least resistance (e.g., a pipe conduit, construction joints, or cracks in the concrete) and ultimately manifested at the crack in the wall in the 78-foot elevation Mechanical Penetration Room and through the gap/penetration where the Spent Fuel Pool cooling return lines intersects the wall at the 92-foot elevation. The mineral deposits have subsequently been removed to restore flow in the telltale drains.

Further investigations conducted within the Station indicated that water from the Spent Fuel Pool had migrated to the Styrofoam-filled seismic gap located between the Unit 1 Fuel Handling Building and the Auxiliary Building. Along the narrow western and southern ends of the Seismic Gap, a flow path exists between the Styrofoam and foundation soils. As such, the potential exists for water in the seismic gap to migrate beyond the limits of the

engineered structures of the Station. Remedial investigation activities were initiated to determine if the Spent Fuel Pool water that had accumulated in the seismic gap had migrated beyond the limits of the engineered features of the building and into the environment (i.e., soil and groundwater in contact with the seismic gap).

Initially, eight groundwater monitoring wells (Wells K through R) were installed in January and February 2003 at locations adjacent to and around the perimeter of the Salem Unit 1 Fuel Handling Building. Analytical results of groundwater samples collected from these monitoring wells indicated that a potential release of water from the Spent Fuel Pool or other plant source to the environment had likely occurred. At this time, the subject remedial investigation was initiated.

The scope of work proposed in the June 2003 RIWP and the RIWP Addendum was designed to determine if the tritium detected in groundwater samples collected from monitoring wells installed adjacent to Salem Unit 1 is a result of a release to the environment from the Unit 1 Spent Fuel Pool, a non-authorized release from other onsite operating or maintenance activities, or elevated background levels of tritium from authorized releases and other operating practices. The proposed scope of work was also designed to assess the potential for: 1) tritium to migrate beyond the property boundaries; 2) human health and environmental risks associated with the tritium detected in groundwater; and, 3) the need for any further action.

The scope of work presented in the June 2003 RIWP and the RIWP Addendum consisted of the following: 1) the installation of an additional 21 monitoring wells and two replacement monitoring wells; 2) the collection and analysis of groundwater samples from the monitoring well network, including a one time event for groundwater age determination and for technetium-99 to definitively identify the Spent Fuel Pool as the source of the tritium; 3) an evaluation of the local and regional geology and hydrogeology including a review of published information and the performance of water level gauging events, slug tests and pumping tests; 4) an evaluation of tidal influences on select water-bearing units beneath the Station; 5) an evaluation of possible sources of the tritium detected in groundwater; 6) an evaluation of facility construction details and the preparation of detailed cross sections to identify potential migration pathways from the seismic gap and to highlight the principal components of the conceptual site model; 7) fate and transport analysis including the refinement of the conceptual site model, the delineation of groundwater flow pathways, and fate and transport calculations to estimate the age of the tritium release and groundwater flow velocity; and, 8) to assess potential health risks to humans and potential impacts to aquatic and terrestrial biota. The following sections provide a summary of the details and results of the remedial investigation activities.

Well Installation, Groundwater Sampling and the Supplemental Investigation

The initial investigation included the installation and sampling of eight monitoring wells or direct-push points (Well K through Well R; M and R being direct-push points). Analytical results of groundwater samples collected from the monitoring wells indicated that tritium was detected at concentrations above 3,000 picocuries per liter (pCi/L), the interim further investigation criterion proposed in the June 2003 RIWP, in groundwater samples collected from Monitoring Wells M, N, O and R. Tritium was also detected in the groundwater sample collected from Well N on January 30, 2003 at a concentration above the New Jersey Groundwater Quality Criterion (GWQC) for tritium in groundwater of Class IIA aquifers (20,000 pCi/L).

Monitoring Wells S through W were installed between May 5 and June 18, 2003 and existing Monitoring Wells M and R were replaced with properly constructed and developed monitoring wells. **Figure ES-1** shows the monitoring well network installed during the remedial investigation. Following installation and development of the new monitoring wells, groundwater samples were collected from the wells and analyzed by Maplewood for tritium, sodium, boron, and gamma-emitting isotopes. All samples were non-detect for gamma-emitting isotopes. In July 2003, all tritium concentrations, with the exception of Monitoring Wells M and S, were below the GWQC of 20,000 pCi/L. The replacement well for Monitoring Well M, within the cofferdam, indicated a tritium concentration of approximately 62,000 pCi/L and Well S, screened in the shallow, water-bearing unit outside of the cofferdam, indicated a tritium concentration of 3,500,000 pCi/L.

A "supplemental" groundwater investigation was initiated in July 2003 in response to the detections of tritium in groundwater samples collected from Well S. The objectives of the supplemental investigation were as follows: 1) determine if the tritium measured in groundwater samples collected from Well S was migrating towards the property boundary; 2) delineate the vertical and horizontal extent of the tritium in groundwater in the vicinity of Well S; and 3) evaluate the potential sources of tritium in Well S. The supplemental investigation consisted of collecting grab groundwater samples from direct-push boreholes and temporary well points screened at various depths and locations along the site boundary, as well as surrounding Well S. Groundwater samples were submitted for analysis for tritium, boron, and gamma-emitting isotopes.

Figure ES-2 shows the 37 proposed boring locations; samples were collected at as many as three depths at each location. Borings 1 through 8 were proposed to evaluate concentrations along the site perimeter to assess the potential for off-site migration. Borings 9 through 18 and Borings 31 through 37 were proposed near Station infrastructure to identify possible sources of tritium. These potential sources include the liquid radioactive waste ("rad waste") line, the Unit 1 Spent Fuel Pool, the Unit 1 refueling water storage tank, and the Unit 1 primary water storage tank. Borings 19 through 30 were proposed in the vicinity and downgradient of Well S to determine the extent of tritium in groundwater.

The findings from the supplemental investigation are summarized as follows: (1) the limit of groundwater concentrations above the GWQC for tritium (20,000 pCi/L) was defined as shown on **Figure ES-2**; (2) an expanded area in the vicinity of Well S with tritium levels above 500,000 pCi/L was quantified as shown on **Figure ES-2**; (3) a completed pathway between a potential source and groundwater was not identified, but tritium concentrations and groundwater flow direction indicate that the southern end of the seismic gap is the likely source of tritium in groundwater; and (4) extensive on-site monitoring of shallow groundwater indicates no tritium above permissible levels has migrated to the Station boundary.

Following completion of the supplemental investigation, the RIWP Addendum was prepared and submitted to the NJDEP-BNE presenting the details and results of remedial investigation activities completed to date. The RIWP Addendum proposed additional remedial investigation activities designed to complete the delineation of groundwater impacts, and the hydrogeologic characterization of the shallow, water-bearing unit. The proposed remedial investigation activities included the installation of 16 additional groundwater monitoring wells.

Between September 2003 and February 2004, the 16 additional groundwater monitoring wells proposed in the RIWP Addendum were installed at the Station. Initially, Monitoring Well Y, Well Z, and Wells AA through AF were installed. Following the collection and analysis of groundwater samples from these wells, and a re-evaluation of groundwater flow dynamics within the shallow, water-bearing unit, Monitoring Well AG (Shallow and Deep), Well AH (Shallow and Deep), Well AI, Well AJ, Well AL, and Well AM were installed to fill data gaps identified. The locations of the wells are shown of **Figure ES-1**.

Groundwater monitoring activities have been ongoing since the installation of Wells K through R during initial Station investigation activities. Initially, groundwater samples were collected on a weekly basis. As the additional monitoring wells were installed, and as a database of groundwater analytical results for the monitoring wells was generated, the monitoring well sampling program was modified. The sampling program is being adaptively managed to provide the investigational data required to meet the current investigation objectives and evaluate changes in tritium concentrations. The adaptive sampling management program is designed to ensure representative data are collected that meet the objectives of the investigation and provide the information necessary to evaluate plume dynamics and migration. The current monitoring plan specifies either biweekly, monthly, or quarterly sampling based upon the analytical history of each well.

Groundwater samples are analyzed for tritium, major cations and anions, and gamma emitting isotopes. Analysis of groundwater samples collected from most of the Station Monitoring Wells has also included a single event analysis for groundwater age determination (by tritium – helium-3 age dating). As proposed in the RIWP Addendum, Tc-99 was also analyzed as a single-event analysis for select monitoring wells to assist in the determination of the source of the tritium.

Groundwater Flow

Groundwater elevations in monitoring wells screened in the shallow, water-bearing unit within the limits of the cofferdam are generally higher than groundwater elevations in monitoring wells screened in the shallow, water-bearing unit outside the limits of the cofferdam. Groundwater flow in the shallow, water-bearing formation is generally from the center of the island (northeast of the Salem Generating Station) towards the Delaware River. Due to permeability differences between the structural fill and the hydraulic fill, groundwater is mounded within the area of the cofferdam. Groundwater flows radially outward from the cofferdam, and the observed mounding effect dissipates quickly.

Water levels in the Vincentown Formation, because it is a confined-unit, are tidally influenced. Water levels can vary as much as four feet per tide cycle depending on the proximity of the well to the Delaware River. To more accurately assess groundwater flow conditions in the Vincentown Formation, water level and tide data were evaluated to characterize groundwater flow conditions during various stages of the tide cycle of the Delaware River. Groundwater flow direction in the Vincentown Formation oscillates with the tides. During the high tide stage of the tide cycle groundwater flow in the Vincentown Formation is perpendicular from the shoreline of the Delaware River in the west and south towards the center of Artificial Island. During the low tide stage of the tide cycle groundwater flow in the Vincentown Formation is from the center of Artificial Island towards the Delaware River. During an intermediate stage of the tide cycle, an observed groundwater saddle is present between the Station and the Delaware River. Groundwater flow to the north and east of the saddle is to the south and east. Groundwater flow to the south and west of the saddle is to the north and east.

Aquifer Testing

Eight pumping tests were performed on seven wells (Wells AB, AC, AD, AI, AJ, AM, and S) to quantify the hydrogeologic characteristics (e.g., hydraulic conductivity) of the shallow, water-bearing unit within the limits of and just south of the cofferdam. The pumping test results indicate a range of transmissivity of 0.337 ft^2/day to 27.7 ft^2/day and hydraulic conductivities of 0.03 ft/day to 2.77 ft/day.

Tidal Investigation

Pressure transducers were installed in Wells L, M, and W between July 29 and August 5, 2003 to evaluate the tidal influences of the Delaware River on site water levels. Well W installed in the riverbed sands and gravels, and Well M screened in the structural fill within the cofferdam showed no water-level response to tidal variations. Well L installed in the Vincentown Formation (the first confined aquifer beneath the site) has a four foot change in water level in response to a six foot change in tide. This response is likely caused by changes in the hydraulic head exerting force on the clay, confining-unit (the aquitard overlying the Vincentown), which based upon site lithology, extends westward beneath the Delaware River. These data indicate that tidal variations in the Delaware River have no effect on the movement of tritiated groundwater identified in the surficial aquifer (sediments above the clay, confining-unit).

Analytical Results

In accordance with the scope of work presented in the June 2003 RIWP and the RIWP Addendum, samples of environmental media (i.e., soil and groundwater) have been collected from various media at the Station to determine the magnitude and extent of the release of water from the Spent Fuel Pool. Additionally, samples were collected from the Spent Fuel Pool, the telltale drains, and from the various sample locations established within the facility. Collectively, the data indicate that water from the Spent Fuel Pool leaked behind the stainless-steel liner into the obstructed telltale drains, migrated through construction joints or minor cracks in the structural concrete and accumulated in the Styrofoam-filled seismic gap. Once there, the Spent Fuel Pool water seeped into the foundation soils along the southern side of the seismic gap. This release of Spent Fuel Pool water has resulted in an area of impacted groundwater extending from the south side of the seismic gap to the circulating water discharge pipes (see **Figure ES-2**).

The water samples collected from within the facility indicated concentrations of tritium, boron, and various gamma-emitting isotopes typical of Spent Fuel Pool water. Groundwater samples collected from outside the facility, which were analyzed for the same suite of parameters, have indicated concentrations of tritium, boron, and one slightly elevated concentration of Tc-99 that suggest that water from the Spent Fuel Pool is the likely source.

The area of groundwater containing elevated tritium extends from the southern end of the Styrofoam seismic gap located between the Salem Auxiliary Building and the Salem Unit 1 Auxiliary Building in a southerly direction toward the circulation water discharge pipes. Groundwater with tritium at concentrations exceeding any regulatory limit has not migrated to the property boundary of the Station. Elevated levels of tritium have only been detected in groundwater samples collected from the shallow, water-bearing unit. There is no evidence that suggests that water from the Spent Fuel Pool has migrated to an underlying aquifer as confirmed by groundwater samples collected from monitoring wells screened in the Vincentown Formation.

Fate and Transport Analysis

Shallow groundwater in the vicinity of the Station has been impacted by a release of water from the Spent Fuel Pool. The pathway from the building to the environment cannot be documented with absolute certainty; however, site evidence indicates the seismic gap between the Salem Unit 1 Fuel Handling Building and Auxiliary Building is the primary release point. The groundwater travel time between the primary release point and the 500,000 pCi/L contour was computed using observed water levels, aquifer properties, facility operations data, groundwater recharge, and helium to tritium ratios. Collectively, these data indicate that the groundwater plume is between 5 and 10 years old.

Health and Environmental Risk Assessment

The principal radionuclide of concern for this remedial investigation is tritium in shallow groundwater adjacent to Salem Generating Station Unit 1. To date, a completed exposure pathway to humans from tritium in shallow groundwater has not been established, nor is there any evidence that significant exposures of biota have occurred.

Conclusions

The results of remedial investigation activities conducted at the PSEG Nuclear, LLC Salem Generating Station, which were conducted in response to the detection of tritium in groundwater, indicate that the source of tritium detected in groundwater was the Spent Fuel Pool, the tritium release to the environment has been stopped, and that tritium has not migrated to the property boundary above any regulatory limit. The following bullets provide a more detailed description of the investigation findings:

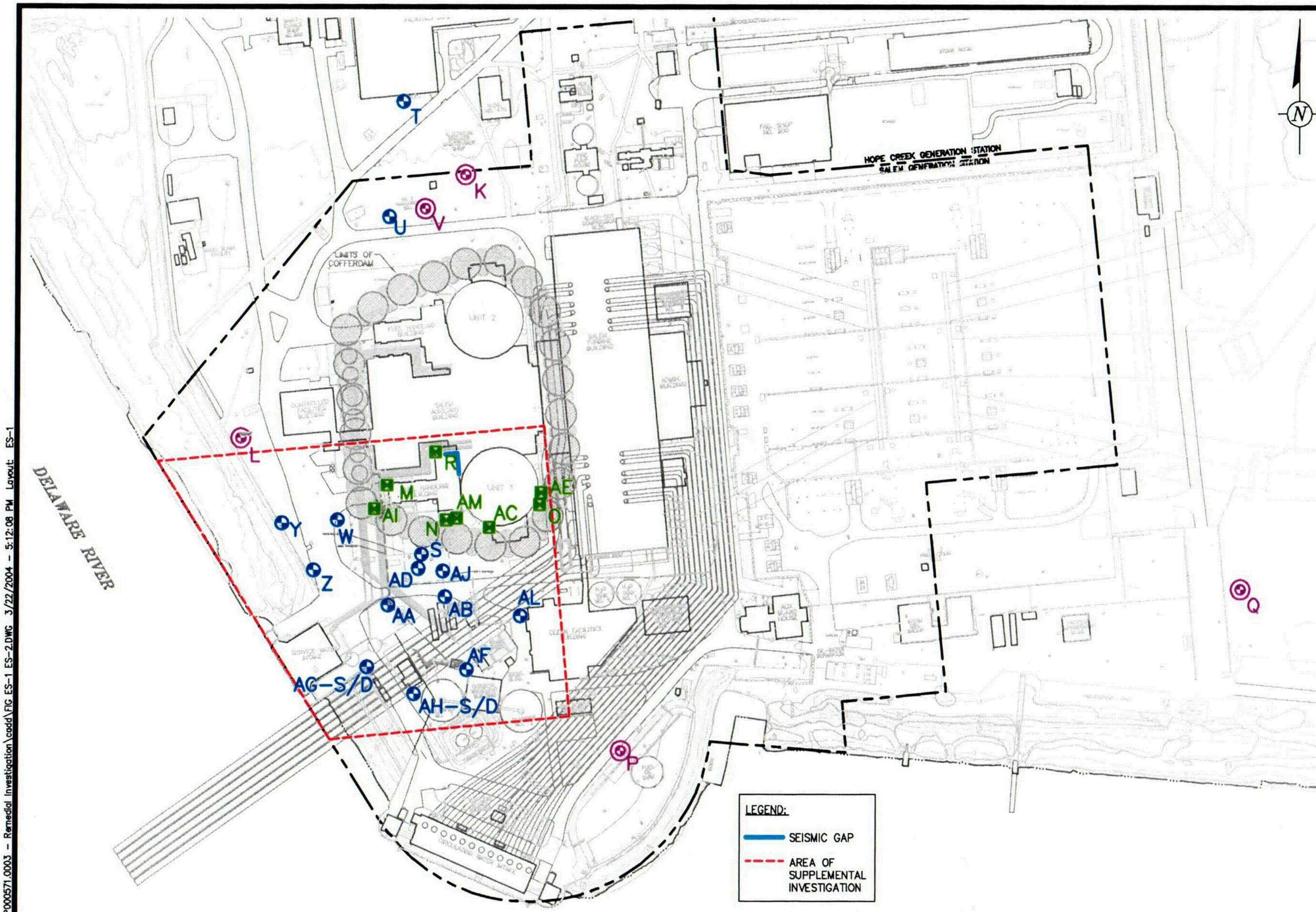
- There was a release of water from the Spent Fuel Pool system resulting from blockage of the telltale drains by mineral precipitates. The telltale drains are a leak monitoring, collection, and drainage mechanism specifically designed to collect leakage that may accumulate behind the stainless steel liner of the Spent Fuel Pool and Refueling Canal. The blockage of the telltale drains resulted in the accumulation of water from the Spent Fuel Pool system (between the liner and the concrete wall) that created hydrostatic head and facilitated migration to the Styrofoam-filled seismic gap located between the Salem Unit 1 Fuel Handling Building and Auxiliary Building. The mineral precipitates have been physically removed to ensure the proper operation of the telltale drains. The process of monitoring the telltale drains is routinely performed to ensure that blockage does not reoccur. Permanent seismic gap drains are being installed on Salem Units 1 and 2, to permit identification, sampling, and drainage of any accumulated water in the seismic gap, and to create an ingradient to the gap;

- The release of water from the Spent Fuel Pool system was investigated through the sampling of monitoring wells installed in the area of Salem Unit 1. The groundwater analytical data collected from the monitoring well network were used to delineate an area of groundwater in the shallow, water-bearing unit that contains elevated tritium. Gamma-emitting isotopes were also monitored in the groundwater samples collected from the monitoring wells because the suspected source of the tritium was the Spent Fuel Pool. No plant related gamma-emitting isotopes have been detected in groundwater samples collected from the monitoring wells;

- The area of groundwater containing elevated tritium extends from the southern end of the Styrofoam seismic gap located between the Salem Unit 1 Fuel Handling Building and the Auxiliary Building in a southerly direction toward the circulation water discharge pipes. Groundwater with tritium at concentrations exceeding any regulatory limit has not migrated to the property boundary of the Station;

- Elevated levels of tritium have only been detected in groundwater samples collected from the shallow, water-bearing unit. There is no evidence that suggests that water from the Spent Fuel Pool has migrated to an underlying aquifer as confirmed by groundwater samples collected from monitoring wells screened in the Vincentown Formation; and,

- A completed exposure pathway to humans from tritium in shallow groundwater has not been established, nor is there any evidence that significant exposures of biota have occurred.



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ARCADIS

DRAWN M. WASILEWSKI	DATE 9/16/03	PROJECT MANAGER P. MILIONIS	DEPARTMENT MANAGER D. FULTON
MONITORING WELL NETWORK FOR THE REMEDIAL INVESTIGATION PSEG NUCLEAR, LLC SALEM GENERATING STATION ARTIFICIAL ISLAND HANCOCK'S BRIDGE, NEW JERSEY		LEAD DESIGN PROF. S. POTTER	CHECKED B. PIERCE
		PROJECT NUMBER NP000571.0003	DRAWING NUMBER ES-1

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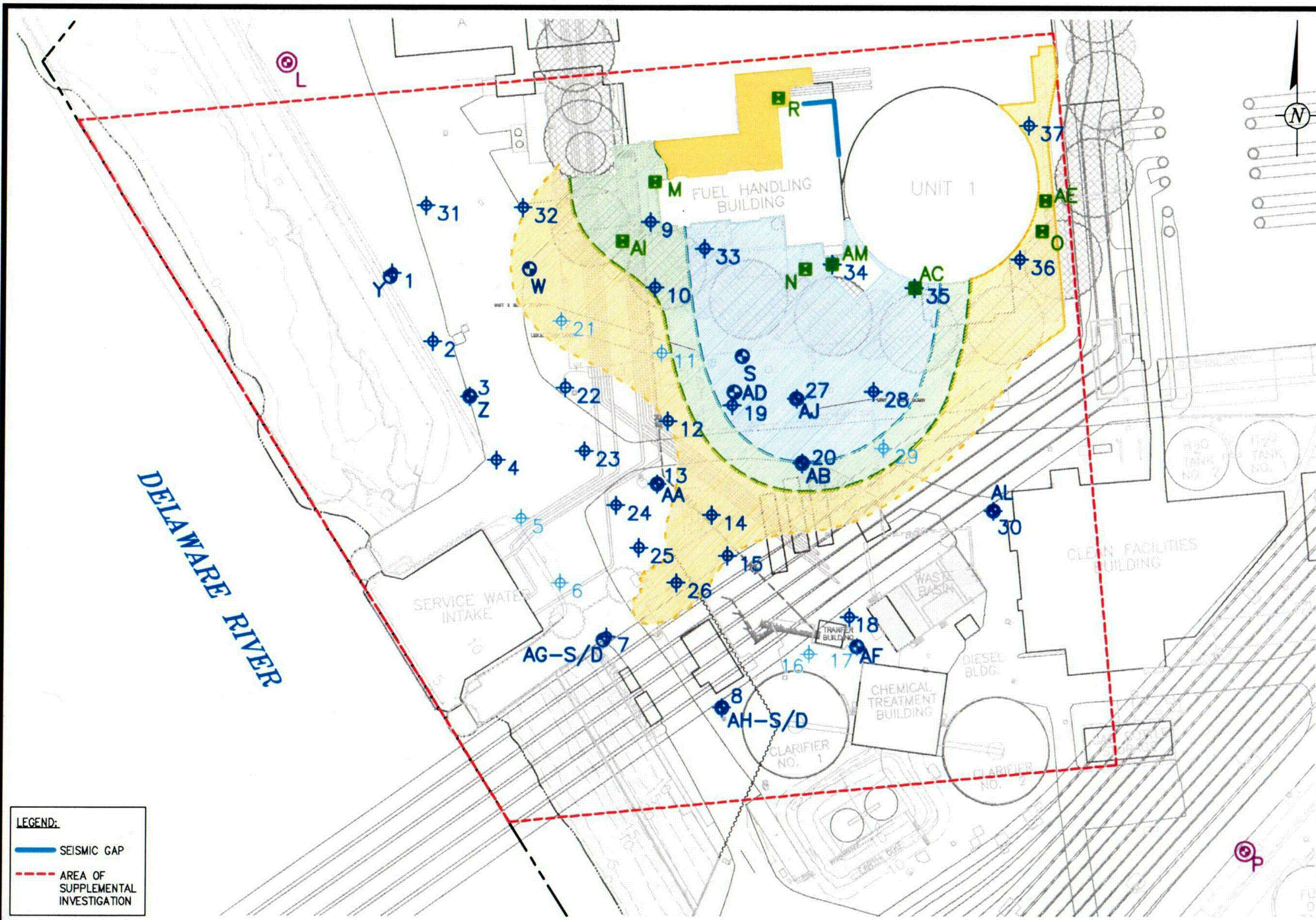

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DRAWN M. WASILEWSKI	DATE 9/16/03	PROJECT MANAGER P. MILIONIS	DEPARTMENT MANAGER D. FULTON
AREA OF TRITIUM LEVELS ABOVE 500,000 pCi/L PSEG NUCLEAR, LLC SALEM GENERATING STATION ARTIFICIAL ISLAND HANCOCK'S BRIDGE, NEW JERSEY		LEAD DESIGN PROF. S. POTTER	CHECKED B. PIERCE
		PROJECT NUMBER NP000571.0003	DRAWING NUMBER ES-2

G:\APROJECT\PSE&G\Salem\NP000571.0003 - Remedial Investigation\cadd\FIG ES-1 ES-2.DWG 3/22/2004 - 5:11:21 PM Layout: ES-2

1 Introduction

ARCADIS, Inc. ("ARCADIS"), on behalf of PSEG Services Corporation ("PSEG SC"), has prepared this Remedial Investigation Report ("RIR") to document the findings of a remedial investigation conducted at the PSEG Nuclear, LLC Salem Generating Station (the "Station") located on Artificial Island in Lower Alloways Creek Township, Salem County, New Jersey. The Station location and layout are shown on **Figures 1** and **2**, respectively. The remedial investigation was conducted in accordance with the Remedial Investigation Work Plan ("June 2003 RIWP") that was submitted to the New Jersey Department of Environmental Protection Bureau of Nuclear Engineering ("NJDEP-BNE") in June 2003. The scope of work outlined in the June 2003 RIWP was designed to investigate the discovery of tritium in the shallow, water-bearing unit at the Station.

A document entitled, "Initial Groundwater Investigation Report and Remedial Investigation Work Plan Addendum" ("RIWP Addendum") was submitted to the NJDEP in January 2004. The RIWP Addendum contained the initial results of the remedial investigation and, based on these results, proposed certain modifications to the June 2003 RIWP.

This RIR contains the results of remedial investigations as described in both the June 2003 RIWP and the RIWP Addendum. The remedial investigation produced a comprehensive body of knowledge regarding the tritium discharge, its fate in the environment, and the physical environment at and in the vicinity of the Station. The findings presented in this RIR will be used as the basis for the development of a remedial action strategy and work plan that will be submitted to the NJDEP-BNE under separate cover.

1.1 Project Background

On September 18, 2002, the Station Radiation Protection staff reported measuring low-level radioactivity on the shoes of technicians inside the radiologically controlled Auxiliary Building. An initial facility investigation led to the discovery of a radioactive "chalk-like" substance adhering to the west wall in the 78-foot Mechanical Penetration Room of the Unit 1 Auxiliary Building. The buildup of the "chalk-like" deposits was removed and an active seep of water into the 78-foot Mechanical Penetration Room was observed. Further investigation revealed a second leak at the 92-foot elevation of the Unit 1 Spent Fuel Pool cooling line, adjacent to the pipe penetration through the concrete wall.

As presented in Section 5, sample points were established for the collection and analysis of water samples from the observed leaks. Samples collected from the sample points were analyzed for tritium, major cations and anions, and gamma-emitting isotopes to determine the concentrations of constituents of concern in the water samples, to evaluate the potential age of the leak, and to evaluate a potential source of the water. Analytical results of the samples indicated that the water from both leaks had characteristics of Spent Fuel Pool water and that a leak from the Spent Fuel Pool system had likely occurred.

The Salem Generating Station Unit 1 Spent Fuel Pool is lined with stainless steel. Behind the stainless steel liner are liner drains (commonly referred to as "telltale drains") that are used as a combined leak monitoring, collection, and drainage mechanism. The telltale drains are specifically designed to collect leakage that may accumulate behind the stainless steel liner of the Spent Fuel Pool and Refueling Canal. There are ten telltale drains associated with the Salem Generating Station Unit 1 Spent Fuel Pool that are identified as Drain Nos. 1 through 10. There are seven telltale drains associated with the Salem Generating Station Unit 1 Refueling Canal that are identified as Drain Nos. 11 through 17. Drains No. 11 through 17 are designed to monitor, collect, and drain leakage from the Refueling Canal that is associated with the Spent Fuel Pool.

A series of water samples was collected from the telltale drains to characterize the water that had accumulated. Analytical results of the water samples, discussed in further detail in Section 5, indicated that the likely source of water in the Spent Fuel Pool telltale drains was Spent Fuel Pool water, while the source of water in the Refueling Canal telltale drains indicated a possible mixing of water from the Spent Fuel Pool system with sodium, which is uncharacteristic of water from the Spent Fuel Pool system. A lack of chloride detected in water samples collected from the Refueling Canal telltale drains suggests that the sodium concentrations are likely from the interaction of the Spent Fuel Pool water with the structural concrete.

On January 31, 2003, a fiber optic examination of the telltale drains indicated a blockage by mineral deposits of the No. 4 and No. 5 drains beneath the welds in the stainless-steel liner of the Spent Fuel Pool, which obstructed the flow of water that leaked behind the stainless-steel liner. While obstructed, the flow of water from leak(s) in the Spent Fuel Pool liner was likely forced between the liner plates and the structural concrete base and walls of the Fuel Handling Building to establish hydraulic equilibrium with the water level in the Spent Fuel Pool. The Spent Fuel Pool water likely migrated along the paths of least resistance (e.g., a pipe conduit, construction joints, or cracks in the concrete) and ultimately manifested at the crack in the wall in the 78-foot elevation Mechanical Penetration Room and through the gap/penetration where the Spent Fuel Pool cooling return lines intersects the wall at the 92-foot elevation.

The mineral deposits were physically removed from the telltale drains to restore flow, which was measured to be approximately 100 gallons per day (gpd), which is within the design parameters of the leak detection, collection and monitoring system and is processed through the routine waste treatment processes. The process of monitoring and removing the mineral deposits, as needed, has been and will continue to be conducted to ensure that the telltale drains do not become obstructed in the future.

Analytical results of water samples collected from the observed leaks (78-foot elevation Mechanical Penetration Room and through the gap where the Spent Fuel Pool cooling return lines intersects the wall at the 92-foot elevation) and subsequent investigations of the Unit 1 telltale drains indicated that further investigation was necessary to: 1) characterize the observed leaks and determine their source; 2) determine the extent of the leaks within the Salem Generating Station Auxiliary and Spent Fuel Pool Buildings; and, 3) determine the extent of the impact from the leak, if any, into the environment (soil and groundwater in contact with the engineered features of the Station).

Further investigations indicated that water from the Spent Fuel Pool had migrated to the Styrofoam-filled seismic gap located between the Unit 1 Fuel Handling Building and the Auxiliary Building. The details and results of sampling activities that were conducted within the facility to identify the source of the water observed in the 78-foot elevation Mechanical Penetration Room and through the gap where the Spent Fuel Pool cooling return lines intersects the wall at the 92-foot elevation are summarized in Section 5 and are presented in detail in the Investigations of Salem Unit 1 Fuel Pool Leakage – Final Report Summary provided in **Appendix A**.

The Styrofoam-filled seismic gap is approximately six-inches wide and extends vertically from grade (100 feet Plant Datum [PD]) to the top of the concrete foundation of the Fuel Handling Building. A discussion of the lean concrete foundation is presented in Section 4.2.1. The Styrofoam was originally used as a concrete form for the surrounding concrete pour. The Styrofoam was left in place to serve as a seismic gap. Along the narrow western and southern ends of the Seismic Gap, a flowpath exists between the Styrofoam and foundation soils. As such, the potential exists for water in the seismic gap to migrate beyond the limits of the engineered structures of the Station and into the environment.

Following the discovery of water characteristic of the Spent Fuel Pool in the Styrofoam-filled seismic gap, remedial investigation activities were initiated to determine if Spent Fuel Pool water that had accumulated in the seismic gap had migrated beyond the limits of the engineered features of the building and into the environment (i.e., soil and groundwater in contact with the seismic gap). Initially, eight groundwater monitoring wells (Wells K through R) were installed in January and February 2003 adjacent to and around the perimeter of the Fuel Handling Building. Analytical results of groundwater samples collected from these monitoring wells (discussed in more detail in Section 4.2) indicated that a potential release of water from the Spent Fuel Pool or other plant source to the environment had likely occurred. At this time, the subject remedial investigation was initiated.

1.2 Investigation Objectives

As presented in Section 5.3, analytical results of groundwater samples collected from monitoring wells installed adjacent to and around the perimeter of the Unit 1 Fuel Handling Building indicated concentrations of tritium above the New Jersey Groundwater Quality

Criteria ("GWQC") of 20,000 picocuries per liter ("pCi/L"). Other radionuclides were not detected in the groundwater samples at concentrations above background levels.

The scope of work proposed in the June 2003 RIWP and the RIWP Addendum was designed to determine if the tritium detected in groundwater samples collected from monitoring wells installed adjacent to Salem Unit 1 is a result of a release to the environment from the Unit 1 Spent Fuel Pool, a non-authorized release from other onsite operating or maintenance activities, or elevated background levels of tritium from authorized releases and other operating practices. The proposed scope of work was also designed to assess the potential for: 1) tritium to migrate beyond the property boundaries; 2) human health and environmental risks associated with the tritium detected in groundwater; and, 3) the need for any further action.

1.3 Report Organization

This report provides relevant background information, the details and results of remedial investigation activities conducted to date, and proposed activities in the following sections:

- Section 2 – History of Station Operations;
- Section 3 – Station Setting;
- Section 4 - Facility Construction and Local Geology;
- Section 5 – Initial Station Investigation Activities;
- Section 5 – Remedial Investigation Activities;
- Section 7 – Hydrogeologic Evaluation;
- Section 8 – Analytical Results
- Section 9 – Fate and Transport Results
- Section 10 – Health and Environmental Risk Assessment;
- Section 11 – Conclusions and Recommendations; and,
- Section 12 - References

The History of Station Operations section (Section 2) presents information on the Station operating history, historical releases, the area and constituents of concern, as well as regulatory information about the Station.

The Station Setting section (Section 3) presents a description of the setting of the Salem Generating Station, including land use, the estuarine location, topography and station drainage, climate and precipitation, and regional geology and hydrogeology.

The Facility Construction and Local Geology section (Section 4) presents conditions at Artificial Island prior to the construction of the Station and details how the facility construction has altered the local geology.

The Initial Station Investigation Activities section (Section 5) presents the details and results of the initial investigation activities conducted to identify a source of the radioactivity, to characterize the extent of the release within the facility, and to determine if the release of water from the Spent Fuel Pool system has migrated beyond the seismic gap.

The Remedial Investigation Activities section (Section 6) presents a detailed summary of the remedial investigation activities that have been conducted following the submittal of the June 2003 RIWP and the subsequent RIWP Addendum. This section includes the details for the initial station investigation activities, including sampling conducted.

The Hydrogeologic Evaluation section (Section 7) provides the results of hydrogeologic investigation activities, including slug tests and pumping tests, designed to characterize groundwater movement at the Station.

The Analytical Results section (Section 8) provides a summary of analytical results for samples collected to date. The analytical results section includes a discussion regarding the distribution of tritium in groundwater and the results of tritium age-dating analysis and technetium-99 (Tc-99) analysis.

The Fate and Transport Results section (Section 9) discusses potential flow pathways from the facility and the rate of migration of tritium in groundwater.

The Health and Environmental Risk Assessment section (Section 10) presents a discussion regarding potential exposure pathways and the methodology used for evaluating the risk associated with the exposure pathways.

The Conclusions and Recommendations section (Section 11) presents a summary of the findings of the remedial investigation and recommendations for further actions based on the findings.

A list of References is presented in Section 12.

2 History of Station Operations

The following sections present information on the operating history of the Station, the area and constituents of concern, historical spills and releases, as well as regulatory information about the Station.

2.1 Operating History

PSEG Nuclear, LLC operates and is part owner of the Salem Generating Station located on Artificial Island in Lower Alloways Creek Township, Salem County, New Jersey. PSEG Nuclear, LLC (57.41%) and Exelon (42.59%) jointly own the Station. The Salem Generating Station is adjacent to the Hope Creek Generating Station, also located on Artificial Island. Both the Salem and Hope Creek Generating Stations (the Stations) are located on the eastern bank of the Delaware River. The Salem Generating Station encompasses an approximate 26-acre portion of the approximately 740-acre Artificial Island site.

The Salem Generating Station is composed of two nuclear generating units (Units 1 and 2) and one distillate oil fueled combustion turbine unit (Unit 3). Commercial operations of Units 1 and 2 commenced in 1976 and 1981, respectively. The combustion turbine unit commenced operations in 1972. The nuclear generating units operate as base load units and the combustion turbine unit operates as a peaking unit. The Salem Generating Station has a combined generating capacity of over 2,300 MW. Over its operational life, the Salem Generating Station has experienced no significant changes in its operation.

A detailed description of Salem Generating Station's operations and operational history, was prepared for Exhibit C of the September 1999 Industrial Site Recovery Act (ISRA) Non-Applicability Application, as is included in this RIR as **Appendix B**.

2.1.1 Area of Concern

The remedial investigation proposed in the June 2003 RIWP focused on tritium detected in groundwater adjacent to the Salem Generating Station Unit 1 Fuel Handling Building. As stated in Section 1.2, the primary objective of the remedial investigation was to determine if the tritium detected in groundwater samples collected from monitoring wells installed adjacent to Salem Unit 1 is a result of a release to the environment from the Unit 1 Spent Fuel Pool, a non-authorized release from other onsite operating or maintenance activities, or elevated background levels of tritium from authorized releases and other operating practices. Although the suspected source of the tritium in groundwater was the Spent Fuel Pool water that had accumulated in the seismic gap, other potential sources of tritium were evaluated to determine if they were the primary source, or likely contributors to the elevated levels of tritium. These potential sources included the radioactive liquid waste discharge line, the Salem Unit 1 Fuel Transfer Canal, and the steam generator blowdown lines, each of which is shown on **Figure 1**.

To evaluate the radioactive liquid waste discharge line and the Unit 1 Fuel Transfer Canal, PSEG Nuclear, LLC, performed local leak rate tests. Additionally, a pressure test was performed on the radioactive liquid waste discharge line. According to PSEG Nuclear, LLC, the results of both the local leak rate tests and the pressure test indicated that the radioactive liquid waste discharge line and the Unit 1 Fuel Transfer Canal are functioning properly and are not considered sources of tritium (PSEG, verbal communication 2004). The steam generator blowdown lines, which typically contain tritium at concentrations of approximately 6,000 pCi/L, are not considered a significant source of tritium. As such, the steam generator blowdown lines were not tested for integrity.

In addition to the potential point-source contributors of tritium, potential non-point sources such as historical spills and releases were also considered. A summary of historical spills and releases reported within the area of investigation are presented in Section 2.1.2.

2.1.2 Historical Spills and Releases

To evaluate potential sources of the tritium detected in groundwater adjacent to the Salem Generating Station Unit 1 Spent Fuel Pool, PSEG Nuclear, LLC conducted a review of historical data and interviewed Station personnel regarding any historical spills or releases in the area of investigation. According to PSEG Nuclear, LLC, the results of the evaluation indicated that reported events in the area of investigation generally occurred during the early years of the Station's construction and operation (PSEG, verbal communication 2004). Historical spills or releases were reported to the appropriate agencies to the extent that they met the reporting thresholds in affect at the time and resulted in leaks that were managed through the Station's radioactive liquid waste system without entering the environment or to the soil that was removed and properly disposed off-site. These events did not likely result in the elevated levels of tritium detected in groundwater samples collected from Station monitoring wells. This is evidenced by the difference between the recent groundwater analytical results and the quantity and concentration of tritium reported during these events and the corrective actions taken at the time of the events.

2.1.3 Constituents of Concern

The remedial investigation was initiated when water samples collected from the Styrofoam-filled seismic gap indicated the presence of tritium, boron, and various gamma-emitting radioisotopes typical of water from the Spent Fuel Pool. The physical and chemical properties of the constituents detected in the water samples from the seismic gap, are summarized in **Table 1**. These constituents are routinely monitored in groundwater samples collected from the Station monitoring wells. Other than tritium and boron, the physical properties of the constituents identified in the seismic gap will limit their potential migration in the environment. For example, the gamma-emitting cations (e.g., strontium-90, cesium-137, and cobalt-60) in water will tend to bind strongly to soil particles causing them to migrate at least 100 times slower than groundwater. Tc-99, another constituent of spent fuel pool water, has "intermediate" mobility in groundwater (10 to 20 percent of the rate of groundwater). Tritium and boron do not adsorb strongly to soils and migrate with groundwater. No plant related gamma-emitting isotopes have been detected to date in groundwater samples collected from monitoring wells installed at the Station; however, PSEG SC continues to analyze groundwater samples collected from the monitoring wells for gamma-emitting isotopes because the suspected source of the tritium is the Spent Fuel Pool.

The primary constituent of concern for this investigation is tritium in groundwater. Tritium is a radioactive isotope of the element hydrogen. Molecular hydrogen can exist in over 40 forms, most commonly hydrogen, deuterium, and tritium. Tritium is a hydrogen atom that has two additional neutrons in its nucleus. Tritium occurs naturally in the upper atmosphere when high-energy cosmic radiation bombard atmospheric nitrogen and oxygen and splits off a tritium nucleus (spallation); however, the predominant sources of tritium in the post-nuclear era (i.e., anthropogenic tritium) are the explosions of nuclear weapons, the byproduct of nuclear reactors, and commercial production for use in various self-luminescent devices. Although tritium can occur as hydrogen gas, it is most commonly found as a liquid. Tritium, like non-radioactive hydrogen, reacts with oxygen to form tritiated water. Tritiated water is colorless and odorless, has a half-life of 12.3 years, and emits low-energy beta particles that can be measured by liquid scintillation. Standard scintillation methods can routinely detect tritium concentrations of 200 pCi/L and greater.

As proposed in the June 2003 RIWP, two action levels were defined for tritium in groundwater to assist in the evaluation of data generated through the investigation. These action levels are the Interim Further Investigation Criterion and the Further Action Criterion. The Interim Further Investigation Criterion for this investigation is 3,000 pCi/L. The Further Action Criterion for tritium in groundwater is 20,000 pCi/L, which is the New Jersey Groundwater Quality Criteria for tritium in Class II A aquifers. These criterion were used to evaluate the need for further delineation and characterization for tritium detected in groundwater, and the need for any further action (i.e., remediation).

2.2 Regulatory Review

Regulatory oversight for the Salem Generating Station, and other nuclear generating stations, is provided by both federal and state agencies. These agencies ensure that the stations are designed, constructed, licensed and operate in a manner that maximizes the safe containment and management of radioactive materials. These agencies also ensure that sufficient funding mechanisms have been established, are adequately funded, and will be available to decommission the nuclear generating stations at the end of their life cycle.

On the federal and state levels, the United States Nuclear Regulatory Commission (USNRC) and NJDEP-BNE conduct licensing and oversight of nuclear generating facilities. Oversight by the NJDEP-BNE and USNRC includes inspections of nuclear power plants and conducting environmental radiological monitoring.

3 Station Setting

The following sections provide information regarding the setting of the Salem Generating Station, including land use, the estuarine location, topography and station drainage, climate and precipitation, and regional geology and hydrogeology. A more detailed description of the setting of the Station is included in Section C of the ISRA Non-Applicability Application, which is provided in **Appendix B** to this report.

3.1 Land Use

PSEG Nuclear LLC owns and/or controls an approximately 740-acre area of Artificial Island that is situated adjacent to and surrounds the Salem and Hope Creek Generating Stations. This area contains administrative and support facilities used by the Stations, the Hope Creek Switch Yard, the Salem Switch Yard, and undeveloped vacant land. With the exception of the Salem Generating Stations (Units 1 through 3) and the Salem Switchyard, the remaining acreage is considered to be the Hope Creek Generating Station.

The zoning classification for the Salem Generating Station is industrial. The land adjacent to the Salem Generating Station is zoned for industrial and residential or agricultural use.

3.2 Estuarine Location

The Salem Generating Station is located on a portion of Artificial Island that borders the Delaware Estuary. The Estuary, in the location of the Salem Generating Station, is a tidal, brackish river, located in an area designated as Zone 5 by the Delaware River Basin Commission (DRBC).

The United States Army Corps of Engineers, beginning in the early twentieth century, created Artificial Island by depositing dredge spoils within a diked area established around a natural sand bar that projected into the Delaware River. Prior to construction of the Salem Generating Station, the property was vacant, undeveloped, low-lying land.

3.3 Topography and Station Drainage

The topography at the Salem Generating Station is relatively flat with limited local relief. Topographic contours for the Station are included on **Figure 2**.

Stormwater is managed in accordance with the Salem Generating Station New Jersey Pollution Discharge Elimination System (NJPDES) permit and Stormwater Pollution Prevention Plan. Stormwater is collected in storm drains and routed to the Delaware River for discharge. The locations of the storm drains are included on **Figure 2**. Stormwater from the principle petroleum storage and handling areas is routed to the oil/water separator prior to discharge.

3.4 Climate and Precipitation

Salem County is located in southwestern New Jersey. The county's climate is considered to be humid and temperate, as the climate in this county is readily influenced by its proximity to the Delaware Bay. Coastal storms are not uncommon in this region and can produce high winds and heavy rainfall, which can cause wind damage and flooding in low-lying areas (USDA, 1969).

Wind direction in this region is dependent upon the season; during the summer, winds are typically from the southwest while during the winter, winds are commonly from the northwest. Temperatures vary by season and the maximum expected high temperature for a given year is 96 degrees Fahrenheit, while the minimum expected yearly low temperature is minus 2 degrees Fahrenheit. The average annual precipitation total is 39.9 inches.

3.5 Regional Geology and Hydrogeology

The Salem Generating Station is located on the east edge of the Delaware River, seven miles north of the Delaware Bay, eight miles southeast of the City of Salem and about 40 miles south of Philadelphia, Pennsylvania. The Station is located in the Atlantic Coastal Plain Physiographic Province, approximately 19 miles southeast of the contact between the coastal plain sediments and the Appalachian Highlands. This area is characterized by relatively flat to gently undulating terrain, underlain by unconsolidated sediments that increase in thickness to the southeast.

The coastal plain sediments were deposited in marine and non-marine environments. The sediments are between 1,500 and 2,000 feet thick in the vicinity of the Station, and unconformably overlie bedrock. These sediments range in age from Holocene to Cretaceous (0 to 146 million years old), and are comprised of clay, silt, sand, and gravel. Published geologic mapping indicates that the basement rock beneath these sediments (in the area of the Station) is metamorphic schist of the Wissahickon Formation, which is Pre-Cambrian in age (570 to 900 million years old) (USGS 1999).

The shallow, water-bearing unit at the Station consists of approximately 25 to 35 feet of dredge spoils (hydraulic fill), structural fill material, tidal marsh deposits and riverbed deposits. The structural fill replaced the dredge spoils and natural deposits in select locations at the facility during construction of the Station. Additional information regarding the construction of the facility and the composition and nature of the structural fill are provided in Section 4.2.

The geologic formations beneath the shallow, water-bearing unit, in order of increasing depth, are as follows: the Kirkwood Formation; the Vincentown Formation; the Hornerstown-Navesink Aquitard; the Mount Laurel-Wenonah Formations; the Matawan Formation; the Magothy Formation; the Raritan Confining Unit and Aquifer; the Potomac Group; and, the Wissahickon Formation. Regional cross sections trending northeast to southwest (A-A') parallel to the Delaware River, and northwest to southeast (B-B') perpendicular to the river are provided on **Figure 3** (USGS 1999).

The following sections describe in more detail the units of the coastal plain sediments that are encountered in the vicinity of the Station.

3.5.1 Hydraulic Fill

Artificial Island is composed largely of hydraulically placed dredge spoils from construction and maintenance of nearby navigational channels by the United States Army Corps of Engineers. The hydraulic fill is not considered a source of drinking water.

3.5.2 Riverbed Deposits

A relatively thin layer of riverbed deposits underlies the more recent native and anthropogenic deposits composing Artificial Island. The layer consists of an approximate five- to ten-foot layer of discontinuous Quaternary Age deposits consisting primarily of sand with some gravel, silt and clay. The unit appears as a discrete deposit in some borings (Wells U and V). The results of aquifer tests conducted previously have shown the riverbed deposits to have a hydraulic conductivity on the order of 0.01 to 1 ft/day (Dames & Moore 1988, 1974).

3.5.3 Kirkwood Formation

The Kirkwood Formation, which consists of an upper clay-unit and a basal sand unit, separates the Vincentown Formation from the hydraulic fill and riverbed deposits of the shallow, water-bearing unit. The Kirkwood Formation consists of gray clay with trace silt and gravel, and is laterally extensive in the area of the investigation (see **Figure 4**). Conflicting geologic reports suggest that the geologic unit previously interpreted as the Kirkwood Formation may in fact be the Pleistocene Van Sciver Lake Bed deposits (USGS 1979 and 1999). To determine the relative age of this underlying unit, samples of the clay obtained during the drilling of Well V (see Section 6.5) were analyzed to determine the relative age of the unit, which is interpreted to be the Kirkwood Formation based on the age data.

The Kirkwood Formation occurs at or near the surface and is considered unconfined in Salem and Gloucester Counties (USGS 1999). The Kirkwood Formation is composed of micaceous sands and diatomaceous clay, trends from the northeast to the southwest, and dips to the east-southeast. The sand content increases to the east-northeast where the Kirkwood includes the Atlantic City 800-foot sand. In the vicinity of Artificial Island, the unit is primarily composed of hard clays with trace fine micaceous sand and a basal sand unit directly overlying the Vincentown Formation. The basal unit of the Kirkwood Formation is a fine to medium micaceous sand with varying silt content that coarsens with depth (Dames & Moore July 1976). The upper clay in the Kirkwood Formation is considered an aquitard for the Vincentown Formation and the overlying basal sand unit.

3.5.4 Vincentown Formation

The Vincentown Formation is an aquifer of minor importance in some areas. In the vicinity of the Station, the Vincentown Formation has chloride concentrations of 1,800 to 4,300 mg/L preventing the aquifer from being used as a potable water source (Dames & Moore 1988). The Vincentown Formation outcrops over a small area of central Salem County, and trends northeast to southwest and dips to the east-southeast. The Vincentown Formation is composed of sands to silty sand characterized by a glauconitic quality. Confined by the overlying Kirkwood Formation, the Vincentown Formation extends southeast from Keasby Creek to Stow Creek with the greatest thickness (approximately 60 feet) coinciding with Alloways Creek (USGS 1999). The Vincentown thins and narrows to the northeast reaching a minimum thickness between Glassboro and Berlin before again increasing in thickness and lateral extent. The results of aquifer and laboratory tests have shown the Vincentown Formation to have a hydraulic conductivity on the order of 1 to 10 ft/day (USGS 1999; Dames & Moore 1988). The Hornerstown-Navesink Aquitard underlies the Vincentown Formation.

3.5.5 Hornerstown-Navesink Aquitard

The Hornerstown-Navesink Aquitard is considered to be part of a composite confining unit that includes the less permeable portions of the Vincentown and Piney Point Formations. The aquitard is composed of clayey to silty glauconitic green and black sands with a relatively low permeability (USGS 1999). The results of aquifer tests indicate that the Hornerstown-Navesink Aquitard has a vertical hydraulic conductivity on the order of 0.01 ft/day in Salem County (USGS 1999). Qualitative evidence indicates that leakage occurs from the Vincentown through the Hornerstown-Navesink Aquitard to the underlying Mt. Laurel-Wenonah Aquifer (Dames & Moore 1988).

3.5.6 Mt. Laurel-Wenonah Aquifer

The Mt. Laurel-Wenonah Aquifer is considered to be a major aquifer for the region and is composed of slightly glauconitic sand and increasing silt with depth. The Mt. Laurel-Wenonah aquifer is also identified as existing in Delaware by the Delaware Geological

Survey (DGS). The depth to the top of the Mt. Laurel-Wenonah Aquifer is approximately 173 feet in the vicinity of the Station, with the outcrop area extending from slightly west of Salem and extending approximately halfway to Pennsville (Dames & Moore December16, 1968; USGS 1999). The aquifer has a strike of northeast-southwest and dips to the east-southeast. The maximum thickness of the aquifer is approximately parallel to strike and is coincident with Williamstown and Stow Creek. The results of aquifer tests have shown the Mt. Laurel-Wenonah Aquifer to have a hydraulic conductivity on the order of 0.01 to 10 ft/day and a storativity on the order of $1x10^{-5}$ to $1x10^{-4}$ (USGS 1999). The Matawan Aquitard underlies the Mt. Laurel-Wenonah Aquifer.

3.5.7 Matawan Aquitard

The Matawan Aquitard is a composite unit including the Woodbury Clay and Merchantville Formations. The aquitard is predominantly composed of micaceous and glauconitic clay with some sand present. This unit is a major aquitard, conforming to regional strike and dip that may contain a thin water bearing sand in some areas. The New Jersey Geologic Survey (1995) defined the leakance of the aquitard as being on the order of $1x10^{-11}$ to $1x10^{-8}$ feet/day/foot (day^{-1}) in Salem and Gloucester Counties with the greater values in the western portions of the counties. The Matawan Aquitard is the confining unit for the Magothy Aquifer.

3.5.8 Magothy Aquifer

The Magothy Aquifer is composed of fine to coarse-grained sand with local beds of dark gray lignitic clay, and is located at a depth of 445 feet with a thickness of 50 to 100 feet in the vicinity of the Station (Dames & Moore December16, 1968; USGS 1999). The Magothy outcrops just west of Pennsville with the outcrop area following the regional strike of the coastal plain sediments. The Magothy Aquifer dips and thickens to the southeast (USGS 1999), and has been documented by the DGS as existing in Delaware. The results of aquifer tests have shown the Magothy to have a hydraulic conductivity on the order of 100 ft/day and a storativity on the order of $1x10^{-3}$ (USGS 1999; NJGS 1995). The Magothy Formation is separated from the Raritan Formation by an unnamed confining unit.

3.5.9 Raritan Confining Unit

The confining unit separating the Magothy and Raritan aquifers is composed primarily of dense clay at an approximate depth of 490 feet with a thickness of 190 feet including a 22-foot thick sand unit (Dames & Moore December16, 1968; 1988). A leakance on the order of 10^{-11} day^{-1}, increasing up dip, has been used by the NJGS (1995) to characterize the movement of water through the confining unit to the underlying Raritan Aquifer.

3.5.10 Raritan Formation

The Raritan Formation is composed of sand with traces of silt and with occasional lenses of clay appear with increasing frequency down dip. The Raritan is a major aquifer for the region conforming to the regional strike and dip (USGS 1999). The Raritan Aquifer consists of two sandy zones beneath the Station. The first is the 22-foot thick sand mentioned above at a depth of 688 feet often identified with the Raritan Confining Unit. The second includes a 35- and a 24-foot sand located at depths of 766 and 811 feet below ground surface (bgs), respectively (Dames & Moore December 16, 1968). The total thickness of the Raritan Aquifer has not been well quantified in eastern New Jersey (USGS 1999); however, it tends to thicken down dip, has an approximate thickness of 100 feet beneath the Station, and its maximum identified thickness occurs between Pennsville and Salem. The results of aquifer tests have shown the hydraulic conductivity of the Raritan Formation to be on the order of 1 to 1,000 ft/ day and storativity to be on the order of $1x10^{-3}$ to $1x10^{-4}$ (USGS 1999; Dames & Moore 1988). The Raritan Formation is separated from the Potomac Group by a discontinuous confining unit (USGS 1999).

3.5.11 Potomac Group

The Potomac Group is an undifferentiated series of gravel, sand, silt and clay layers separated from the Raritan in some areas by a confining unit. Down dip, the Raritan and Potomac are undifferentiated (USGS 1983). The Potomac Formation is thought to be more than 250 feet thick and is located at a depth of approximately 836 feet beneath the Station with the uppermost sand occurring at 860 feet bgs (Dames & Moore December16, 1968; USGS 1999). The results of aquifer tests in Gloucester County have shown the group to have a hydraulic conductivity on the order of 100 ft/day and a storativity on the order of $1x10^{-5}$ to $1x10^{-4}$ (Barksdale et al. 1958). The Potomac Group is underlain by Pre-Cretaceous bedrock of the Wissahickon Formation (USGS 1999)

3.5.12 Wissahickon Formation

Located at a depth of approximately 1,400 feet, the Wissahickon Formation is primarily composed of metamorphic gneiss and schist (Hardt and Hilton 1969). The bedrock is not considered a significant source of groundwater.

4 Facility Construction and Local Geology

The construction of the Salem Generating Station has caused significant changes to the local geology and hydrogeology. Within the footprint of the cofferdam surrounding Units 1 and 2, the majority of original Artificial Island materials were removed to a depth of 70 feet bgs. Beyond the limits of the cofferdam, sheet piling was driven into the Kirkwood Formation and left in place, portions of the riverbed deposits were excavated and replaced with structural fill, other portions of the riverbed deposits were chemically grouted thereby changing their physical properties, and the foundations of structures, utilities, as well as various buried piping systems, extend below the water table affecting groundwater flow. These issues and their potential influence on groundwater flow and transport are discussed in further detail in Section 8. The following sections describe the conditions at Artificial Island prior to the construction of the Station, and detail how the construction of the Station has altered the local geology.

4.1 Pre-Facility Construction

The Station is located on the southern tip of what was once a natural sand bar projecting into the Delaware River. The area between the sand bar and the mainland had been used as a dredge spoil deposit area. In 1899, a timber sheetpile wall was installed around the perimeter of the sand bar. Over the next 50 or so years the area was used as a spoil deposit area for material collected during the dredging of the Delaware River. Riprap was added to the perimeter when the timbers began to degrade (Dames & Moore February 1974, June 1977). The area landward of Artificial Island has remained a tidal marsh.

4.2 Facility Construction

The construction of the Station has resulted in significant changes to the local geology. It was necessary to remove and rework much of the soil in the area of the present investigation in order to facilitate construction of the Station. This construction process was guided in part by the recommendations of the geotechnical investigation of Artificial Island (Dames and Moore August 28, 1968). This study recommended that the containment, fuel handling and auxiliary buildings be constructed upon a foundation mat placed at a depth of 50 to 70 feet bgs in the Vincentown Formation and recommended that the turbine, service and administration buildings be placed on pilings driven into the Vincentown Formation. This section describes the construction of the Station, which has had a significant impact on local hydrogeology in the area of the investigation. Facility construction details are highlighted on cross section diagrams through various Station features (**Figures 5** through **9**)

4.2.1 Construction of the Cofferdam

The recommendations for the containment, fuel handling, and auxiliary buildings (primary or Class I structures) were implemented by first constructing a cellular cofferdam of welded interlocking sheet piling. The extent of the cofferdam is shown on **Figure 2** and in profile on **Figures 5** and **6**. The cellular cofferdam, which encircled the excavation for all the Class I structures, was constructed at an approximate depth of 23 feet below existing grade (approximately 77 feet plant datum [PD] or -12.92 feet above mean sea level [amsl NAVD 1988]). The cofferdam consists of 24 circular cells, approximately 60.5 feet in diameter with connecting arcs, that were advanced approximately 10 feet into the Vincentown Formation to an elevation of 17 feet PD (-72.92 feet amsl). The cofferdam sections are of two different heights, 50 feet and 60 feet. The elevation of the top of the cofferdam is 77 feet PD (-12.92 feet amsl) on the north, south and west sides. The elevation of the eastern side is 67 feet PD (-22.92 feet amsl) providing access and a foundation for the return circulating water pipes and associated thrust block.

The inside area of the cofferdam sections were excavated to elevation 27 feet PD (-62.92 feet amsl). A vertical steel wall was added inside each individual cofferdam section to divide the sections approximately in half. The inner half of the individual cofferdam sections, or the section facing the building foundations, was then filled to the top with lean concrete. The area contained by the entire cofferdam structure was then excavated to the Vincentown Formation for placement of the lean concrete mat that served as the foundation for the construction of the structures within the cofferdam. During this stage of the excavation, qualified personnel visually inspected the bottom of the excavation to verify that the excavation had reached the top of Vincentown Formation prior to placing any lean concrete.

Prior to the completion of the excavation, at approximately elevation 45 feet PD (-44.92 feet amsl), 15 exploratory borings were drilled through the remaining Kirkwood Formation and into the underlying Vincentown to verify the depth to the formation. These additional borings showed no measurable differences from the study borings. After the Vincentown Formation had been exposed, an additional six test borings were advanced in the excavated area into the underlying Vincentown Formation to verify and ensure that the Vincentown Formation directly supported the foundation mat. Four of these borings were drilled under the Unit 2 Reactor Containment and two borings were drilled under the Unit 1 Reactor Containment. All of the borings penetrated a minimum of 20 feet into the underlying Vincentown Formation. Based on a review of available documents, the top of the Vincentown Formation in the area of the cofferdam ranges between 27 and 30 feet PD (-62.92 to –65.92 feet amsl).

When the surface of the Vincentown Formation was reached, the area was cleared of loose soil and lean concrete was poured directly onto the exposed Vincentown Formation.

Because the latter stages of the excavation were performed in freezing temperatures, a layer of material was left in place to insulate the Vincentown Formation until the concrete was ready to pour. In cases where the top of the Vincentown Formation did freeze prior to pouring of the concrete, the frozen soils were excavated or thawed prior to starting the pour. The station construction drawings indicate that the base of the first lean concrete pour was at 30 feet PD (-59.92).

4.2.1.1 Construction Within the Cofferdam

The cofferdam serves as a basin in which the Class I structures were constructed. Prior to construction of the primary structures, a lean concrete mat was placed on top of the Vincentown Formation for support of the structures. Following placement of the lean concrete, the Auxiliary Building, Fuel Handling Buildings and Reactor Containment Buildings were constructed. The remainder of the excavation within the cofferdam was then backfilled with structural fill meeting the design specifications of the Station. The following sections provide the details of these construction activities.

4.2.1.1.1 Lean Concrete

The lean concrete was placed in multiple pours. The initial lean concrete pour had a uniform thickness of 5.75 feet within the entire cofferdam area and went from elevation 30 feet to 35.75 feet PD (-59.92 to –54.17 feet amsl). As noted previously, the top of the Vincentown Formation in the area of the Station varies between 27 and 30 feet PD (-62.92 to –65.92 feet amsl). Review of available documentation indicates that the base for the first lean concrete pour was essentially uniform at 30 feet PD (-62.92 feet amsl) and that a soil blanket up to 3 feet thick in some areas was placed on top of the Vincentown Formation.

The second lean concrete pour went from elevation 35.75 feet PD (–54.17 feet amsl) to 45.75 feet PD (-44.17 feet amsl) for an overall thickness of 10 feet. The second pour covered the entire area within the cofferdam with the exception of the Reactor Pit within the Containment Building and the RHR pump pit within the Auxiliary Building. These areas did not receive additional lean concrete beyond the first pour.

The third lean concrete pour went from elevation 45.75 feet PD (-44.17 feet amsl) to 59.75 feet PD (-30.17 feet amsl) for an overall thickness of 14 feet. The third pour covered the entire area within the cofferdam except for the Reactor Pit within the Containment Building, and the residual heat removal (RHR) pump pit within the Auxiliary Building. In the area of the Auxiliary Building along the station centerline, the third pour only reached an elevation of 53.75 feet PD (- 36.17 feet amsl). There is also a sloped area running southeast from the RHR pump pit within the Auxiliary Building up to the cofferdam area that did not reach an elevation 53.75 feet PD (- 36.17 feet amsl).

The fourth and fifth lean concrete pours were limited to the area under the Fuel Handling Buildings and a portion of the Auxiliary Buildings. The fourth pour went from elevation 59.75 feet PD (-29.17 feet amsl) to an elevation of 69.75 feet PD (-19.17 feet amsl). The fifth pour brought the elevation of the lean concrete to 77.75 feet PD (-12.17 feet amsl). The overall thickness of the fourth and fifth pours combined was 18.25 feet 3 inches. The primary purpose of these pours was to provide the base for the Fuel Handling Building.

After the lean concrete pour was completed, the subgrade exterior walls and foundations were waterproofed. A rubber waterproof membrane was installed under all foundations and was extended vertically up to 6 inches below yard grade. The horizontal waterproofing membrane was constructed of 1/16-inch thick Ethylene Propylene Diene Monomers (EPDM rubber). A 1/8-inch thick hard board was installed over the membrane and then a concrete protection course approximately 3 inches thick was installed over the hard board. After construction, the waterproofing membrane was extended vertically up the foundation walls with 3/64-inch thick nylon reinforced rubber that was protected with 1/8-inch thick hardboard.

The individual foundations for the Reactor Containments, Auxiliary, and Fuel Handling Buildings were placed on top of the completed lean concrete. These buildings were designed to be separate structures sitting on the same base mat of lean concrete. To accomplish this design, the base mat structural concrete for these buildings was kept as separate structures with seismic clearance between the base mats.

4.2.1.1.2 Structural Concrete

Auxiliary Building

The base mat structural concrete under the Auxiliary Building in the area of the RHR pump pit starts at elevation 36 feet PD (-53.92 feet amsl) and extends up to approximate elevation 45 feet PD (-44.92 feet amsl). In the area of the Containment Building sumps this base mat extends from elevation 36 feet PD (-53.92 feet amsl) to an elevation of 60 feet PD (-29.92 feet amsl) where it completes the foundation structure for the Containment Building base mat. The base mat structural concrete under the center section of the Auxiliary Building starts at elevation 54 feet PD (-35.92 feet amsl) and extends up to elevation 64 feet PD (-25.92 feet amsl). The remainder of the Auxiliary Building walls and levels are continued up from these base mats to complete the structure.

Reactor Containment

The structural concrete base mat for the Containment Building that completed the reactor pit area to an approximate elevation of 52 feet PD (-37.92 feet amsl) and the remainder of the containment base mat to an elevation of 75.5 feet PD (-14.42 feet amsl). This surface was then covered with a stainless steel liner plate and topped with concrete. The total thickness of the stainless steel liner and concrete is 0.5 feet. Once the reactor pit area base mat was completed to an elevation of 59.75 feet PD (-30.17 feet amsl), the reactor containment base mats for Salem Units 1 and 2 were poured in 6 and 8 circular segments, respectively. Vertical construction joints were constructed with expanded wire mesh. No horizontal joints were permitted. This flat concrete base mat is approximately 16-feet thick with a liner plate located on top of this mat. Once the base mat and liner plate was completed, the finished concrete floor of the containment was poured and the containment structure completed.

The underground portion of the containment structure is waterproofed in order to avoid seepage of groundwater through cracks in the concrete. The waterproofing consists of an impervious membrane that is placed under the mat and on the outside of the walls. The EPDM membrane is designed to resist tearing during handling and when backfill is placed against it.

Fuel Handling Building

The Fuel Handling Building base mat structural concrete was poured from the top of the lean concrete at approximate elevation 77.75 feet PD (-12.17 feet amsl). The Spent Fuel Pool and the Fuel Transfer Pool were included in the first two structural concrete pours with approximate base elevations of 89.5 feet PD (-0.42 feet amsl) and 86 feet PD (-3.92 feet amsl), respectively.

4.2.1.1.3 Structural Fill

The soils removed from within the cofferdam were not used to backfill the completed structure because the hydraulically placed fill underlying Artificial Island did not meet the building design specifications for the Station. Therefore, it was necessary to import construction or structural fill to build the facility. The structural fill was placed between and around the Auxiliary Building, Fuel Handling Buildings, Units 1 and 2, portions of the cofferdam, above the return circulating water pipes, and from the top of the Kirkwood Formation to the land surface in the portions of the area between the cofferdam and the circulating water discharge pipes. This material was used extensively in the area of Unit 1 and the circulation water pipes.

4.2.2 Construction of the Service Water Intake Structure

The service water intake structure, shown on **Figure 2**, was constructed by driving sheet piles into the Vincentown Formation, and dewatering and excavating the enclosed soils (Dames & Moore August 28, 1968). The foundation of the structure lies upon a lean concrete pour placed upon the top of the Vincentown Formation. The base of the lean concrete is at elevation 45 to 50 feet PD (-44.92 to –39.92 feet amsl) (Dames & Moore June 3, 1970). This structure extends from the top of the Kirkwood Formation to the land surface preventing groundwater flow from this area to the Delaware River.

4.2.3 Construction of the Service Water Pipes

The original material in the locations of the service water pipes was excavated to the top of the riverbed deposits that overly the Kirkwood Formation. Structural backfill was placed above the riverbed deposits. The structural fill was compacted to 98 percent of optimum and used as the foundation for the service water lines (Dames & Moore August 28, 1968). Compaction is the process of increasing soil unit weight by forcing soil solids into a tighter state and reducing soil voids. This process strengthens soils and reduces hydraulic conductivity. Optimum compaction is the maximum soil weight that can be achieved at a given moisture content. The service water lines are two-foot diameter and are located at varying depths below ground surface throughout the area of investigation. The location of the lines is shown on **Figure 2**.

4.2.4 Construction of the Circulating Water Intake Structure

The circulating water intake structure is shown on **Figure 2**. The area of the intakes for the circulating water pipes was dredged to elevation 56 feet PD (-33.92 feet amsl). The surrounding structure was constructed on piles cut off at elevation 56 feet PD (-33.92 feet amsl). The top of the Vincentown Formation in this area is between elevation 40 and 53 feet PD (-49.92 and –36.92 feet amsl) (Dames & Moore June 3, 1970). This structure extends from the top of the Kirkwood Formation to the land surface preventing groundwater flow from this area to the Delaware River.

4.2.5 Construction of the Circulating Water Pipes

Water in the circulating water system is drawn from near shore, through 12, 7-foot diameter water intake lines. Water passes through the turbine building and returns to the Delaware River through 6, 10-foot diameter pipes extending approximately 500-feet off shore and discharging at an elevation of 53 feet PD (-36.92 feet amsl). The location of the lines is shown on **Figure 2**. The return circulating water lines are an important subsurface feature affecting groundwater flow in the area of investigation. They were constructed by sheet piling and excavation dewatering of the overlying sediments to the top of the Kirkwood Formation. Concrete footers were constructed perpendicular to the pipes from the turbine building to the shoreline. Between the concrete footers, crushed compacted concrete was placed. The surface of this foundation is sloped uniformly from an elevation of approximately 65 feet PD (-24.92 feet amsl) near the shore to about 75 feet PD (-14.92 feet amsl) near the turbine building. Following construction, lean concrete was poured between the pipes. These pipes and underlying foundations are a buried flow barrier, extending vertically 15 to 20 feet from the top of the Kirkwood Formation limiting southward groundwater movement. Construction of the return circulating water pipes were completed by placement and compaction of structural fill from near the top of the pipes to the present land surface.

4.2.6 Sheet Pile – Circulating Water Intake Structure to the Service Water Intake Structure

Groundwater movement toward the Delaware River is also restricted between the Circulating Water and the Service Water Intake Structures by interlocking sheet pile. The sheet piling is considered to be good barrier to flow as cathodic protection is used to control corrosion. The sheet piling was driven through the surficial aquifer into the first aquitard beneath Artificial Island (the Kirkwood Formation) during construction of the Salem Generating Station. The sheet piling is located as shown on **Figure 9**. Where the sheet piling is indicated using a dark black line, the elevation of the top is above the current water table; the sheet piling acts as a dam limiting the horizontal movement of water. Where the sheet piling is indicated using a gray line, the elevation of the top is below the current water table; groundwater is moving across the top of the sheet piling toward the Delaware River.

4.3 Local Geology

Certain information made available through the design and construction of the Station were used in conjunction with data obtained during the remedial investigation to define the geology as it currently exists. The Station geology is tied into the regional geology via the Vincentown Formation. During construction many areas were excavated down to the top of the Vincentown Formation, as such, it is a logical reference point. In the vicinity of the Station, the Vincentown Formation is overlain by the Kirkwood Formation, including the Kirkwood basal sand unit and the Kirkwood Aquitard, the riverbed deposits, hydraulically placed dredge spoils, and in some locations structural backfill. In most cases, the properties of these formations have been described in the above sections.

The upper surface of the Vincentown Formation in the area of the Station ranges between 27 and 30 feet PD (-62.92 to –65.92 feet amsl). The Vincentown is composed of glauconitic sands to silty sands with varying degrees of calcite cementation. The Kirkwood basal sand overlies the Vincentown Formation in the vicinity of the Station.

The Kirkwood basal sand is a reddish brown fine to medium sand coarsening with depth. The sand is variable in thickness at the Station and has been misidentified as the deeper aquifer in previous investigations (Dames & Moore May 23, 1974). Pumping tests conducted in the Kirkwood basal sand and Vincentown Formation have shown the units to have a hydraulic conductivity on the order of $1x10^{-3}$ cm/s and a storativity with a magnitude on the order of $1x10^{-4}$ to $1x10^{-3}$ (Dames & Moore May 23, 1974).

The Kirkwood Aquitard extends from the top of the Kirkwood basal sand to approximately 60 feet PD (-30.53 feet amsl). The Kirkwood Aquitard is composed of hard tan to gray clay with some sand and silt ten to twenty feet in thickness. The Kirkwood Aquitard is overlain by the riverbed deposits of the shallow, water-bearing unit.

The riverbed deposits are a dense, dark gray to tan, fine to medium sand with varying gravel content. With an upper elevation of approximately 65 feet PD (-25.53 feet amsl), the riverbed sand and gravel ranges in thickness from approximately 1 to 9 feet at the facility. The riverbed sand and gravel is overlain by hydraulic fill in some areas and structural fill in others, and is considered a leaky confined aquifer (Dames & Moore February 27, 1981 and December 23, 1992).

The hydraulic fill is a dark gray estuarial silt and clay with a hydraulic conductivity 1,000 to 10,000 times less than the underlying riverbed sand and gravel unit (Dames & Moore December 23, 1992). The hydraulic fill extends approximately from an elevation of 35 feet PD (-55.53 feet amsl) to surface grade in areas that remained undisturbed during the construction of the generating station. In other areas, the hydraulic fill has been entirely removed and replaced with structural fill.

The structural fill used at the station was obtained from a number of sources in New Jersey and Delaware. One fill source used in the area of this investigation was the Hinchner Pit. While the location of the borrow source was not identified, the material was described as yellowish-brown fine to medium sand with a trace of silt and clay (Dames & Moore June 20, 1972).

5 Initial Station Investigation Activities

Samples of leaking water were collected from three locations in an effort to characterize the nature of the leak detected from the west wall of the 78-foot Mechanical Penetration Room of the Unit 1 Auxiliary Building and from the penetration of the Unit 1 Spent Fuel Pool cooling line at the 92-foot elevation. The three sample locations were as follows:

- A drip bag was installed at the crack in the wall of the 78-foot Mechanical Penetration Room;
- A catch tray with a sample tube was placed under the Spent Fuel Pool cooling line at the interface between the Auxiliary Building and the Fuel Handling Building; and,
- A sample tube was established in the water stop located at the penetration between the Auxiliary Building and the Fuel Handling Building.

Samples collected from these locations were analyzed for tritium, major cations and anions, and gamma-emitting isotopes to determine the concentrations of constituents of concern in the water samples and to evaluate a potential source of the water. Analytical results of the samples were compared with analytical results of water samples collected from the Spent Fuel Pool and the telltale drains. The analytical results of the initial samples from these locations indicated that the water from the leaks had characteristics of Spent Fuel Pool water and that a leak from the Spent Fuel Pool system had occurred.

A series of samples from these initially established locations, as well as other locations subsequently established within the Station were collected and analyzed to characterize the leak from the Spent Fuel Pool system within the limits of the facility structures. The results of these sampling activities are presented in the Investigations of Salem Unit 1 Fuel Pool Leakage – Final Report Summary, which is provided in **Appendix A**.

An investigation of environmental media (i.e., groundwater and soil) in response to the leak from the Spent Fuel Pool was initiated in October 2002. These activities were conducted in three distinct phases (herein identified as Phase I, II, and III) each designed to determine the nature and extent of the release of water from the Spent Fuel Pool. Phases I and II of the investigation consisted of the collection and analysis of samples from within the facility structures, from the shallow, groundwater unit beneath the Station, and from select production and monitoring wells located adjacent to the Station. Sections 5.1 and 5.2 present the details of Phases I and II, respectively. Details of Phase III investigation activities, which included the installation and sampling of eight groundwater monitoring wells (Wells K through R), are presented in Section 5.3.

5.1 Phase I

The objectives of Phase I of the investigation were to further characterize the leak in the 78-foot elevation Mechanical Penetration Room, and to assess the likelihood that the leak had migrated to other locations within the Station, or beyond the limits of the Station structures and into the environment. The sampling program that comprised Phase I of the investigation included the following:

- Two groundwater samples were collected from inside the area through the "Door to Nowhere" in the 100-foot elevation Auxiliary Building. The sample locations consisted of the following:
    - Above the fuel transfer canal in the space between the Containment Building and the Fuel Handling Building (Sample A1). This required the removal of sandbags to a depth that groundwater was encountered.
    - Immediately inside the door to the right and next to the Fuel Handling Building (Sample A2).
- A groundwater sample was collected from inside the security gate at the northeast corner of the Fuel Handling Building yard area (Sample B).
- Water samples were collected from catch basins numbers 26 (Sample C26) and 33 (Sample C33).
- A water sample was collected from the drain line located in the 78-foot elevation Mechanical Penetration Room (Sample D).
- An additional water sample was collected from the active drip located in the area of the crack observed in the 78-foot elevation Penetration Room (Sample E).

The Phase I sample locations are shown on **Figure 10**. The groundwater samples (Samples A1, A2, and B) were discrete samples collected from a depth of four to five feet bgs (plant datum, [PD], 96 to 95 feet) in the area surrounding the Mechanical Penetration Room. The water samples collected from the catch basins (Samples C26 and C33), the drain line located in the 78-foot elevation Mechanical Penetration Room (Sample D), and the active drip from the crack in the wall of the 78-foot elevation Mechanical Penetration Room were grab samples. The samples (both water and groundwater) were analyzed onsite for gamma emitting isotopes. The analysis of Sample E included boron.

Analytical results of the water samples collected during Phase I are summarized in **Table 2**. Analytical results of water samples collected in the shallow subsurface (five feet bgs) did not indicate concentrations of target analytes that would indicate a release of water from the Spent Fuel Pool.

Analytical results of Sample E, collected from the active drip in the crack observed in the 78-foot elevation penetration room, indicated a boron concentration of 2,600 milligrams-per liter (mg/L), a cesium-134 (Cs-134) concentration of 118,000 pCi/L, and a cesium-137 (Cs-137) concentration of 320,000 pCi/L. These concentrations are characteristic of water from the Spent Fuel Pool.

5.2 Phase II

The objective of Phase II of the investigation was to evaluate the extent of contamination in groundwater and the Styrofoam-filled seismic gap between the Salem Auxiliary Building and the Salem Unit 1 Fuel Handling Building. The sampling program that comprised Phase II of the investigation is described in more detail below:

- On December 12 and 13, 2002, the PSEG Salem Generating Station Chemistry Division (PSEG Chemistry) collected groundwater samples from select production and monitoring wells installed within the vicinity of the Station. The samples were collected to assess whether the leak detected within the facility had migrated beyond the engineered structures of the Station. The groundwater samples were submitted to the PSEG SC Maplewood Laboratory and Testing Services (Maplewood) for analysis for tritium and gamma-emitting isotopes. The water sample collected from Well G was also analyzed for sodium, chloride, and boron. Analytical results of the groundwater samples, summarized in **Table 3**, did not indicate concentrations of constituents of concern above expected background concentrations. Although the radium detected in the Hope Creek and Salem production wells is naturally occurring, the concentrations indicated by groundwater samples collected from the wells were above the New Jersey Drinking Water Standard. Since the production wells may be used for drinking water, the NJDEP requested that PSEG Nuclear, LLC collect water samples from the facility water distribution network and submit those samples for gross alpha analysis. Analytical results of the water samples did not indicate gross alpha activity above 5 pCi/L. As such, further radium analysis of the wells is not required.

- On December 19 and 20, 2002, two direct-push discrete water samplers (DP-1 and DP-2) were advanced into the Styrofoam-filled Seismic Gap between the Salem Auxiliary Building and the Salem Unit 1 Fuel Handling Building. The water samplers consisted of one and one quarter-inch steel rods with a two-foot mill slotted sample screen. Water samples were obtained using quarter-inch polyethylene tubing and a peristaltic pump. The locations of DP-1 and DP-2 are shown on **Figure 10**. DP-1 was installed vertically along the northeast exterior wall of the Fuel Handling Building. DP-2 was installed on a 45-degree angle from the area of the "door to nowhere" into the Styrofoam to a depth that corresponded with the leak observed at the 78-foot elevation in the Mechanical Penetration Room. Analytical results of water samples collected from DP-1 and DP-2, summarized in **Table 3**, indicated concentrations of constituents of concern (primarily boron and tritium) that are consistent with Spent Fuel Pool water.

Results of the Phase II investigation indicated that water in the Styrofoam-filled Seismic Gap and the water observed leaking into the 78-foot elevation of the Mechanical Penetration Room had characteristics of Spent Fuel Pool water and likely had accumulated when the Spent Fuel Pool telltale drains had become obstructed.

5.3 Phase III

Phase III of the investigation was initiated following the discovery of water containing boron and various radioisotopes characteristic of water from the Spent Fuel Pool in the Styrofoam-filled Seismic Gap and was designed to determine if water leaking from the Spent Fuel Pool had migrated into the environment (i.e., soil and groundwater underlying the facility) adjacent to the Fuel Handling Building. This phase of the investigation involved the installation and collection of groundwater samples from eight monitoring wells adjacent to and around the perimeter of the Fuel Handling Building.

The installation of the eight monitoring wells was completed in two sub-phases (III (a) and III (b)). The locations of the Sub-Phase III (a) and Sub-Phase III (b) Monitoring Wells are shown on **Figure 11**. Monitoring Wells M, N, O, and R installed during Phase III (a), were installed at locations between the Phase II direct push discrete water samplers (DP-1 and DP-2) and the cofferdam, which bounds the perimeter of the Salem Generating Station foundation. The Sub-Phase III (a) wells were installed to a total depth of 20 feet bgs. The depths of the wells considered the elevation of the lean concrete foundation within the cofferdam. As discussed in Section 4.2.2, the elevation of the lean concrete foundation is approximately 78 feet PD. Each monitoring well was constructed with a ten-foot screened interval (10 to 20-feet bgs). Monitoring Wells M and R are constructed of 1¼-inch steel and were installed using direct push (i.e., Geoprobe®) technology due to access restrictions. Monitoring Wells N and O are constructed of two-inch PVC and were installed using hollow-stem auger drilling equipment.

Monitoring Wells K, L, P, and Q installed during Phase III (b), were installed outside the limits of the cofferdam. The Sub-Phase III (b) wells were installed into the Vincentown Formation using hollow-stem auger drilling equipment to a total depth of 80 feet bgs (20 feet PD), which corresponds with an elevation of ten feet below the Salem Generating Station foundation. The Sub-Phase III (b) monitoring wells, designed to monitor groundwater quality outside of the cofferdam, were constructed with a ten-foot screened interval (70 to 80-feet bgs) and are constructed of two-inch diameter PVC well materials. A summary of the well construction details for the Station monitoring wells is presented in **Table 4,** and well construction logs and boring logs are included in **Appendix C**.

Following installation and development of the monitoring wells, groundwater samples were collected on a periodic basis to assess groundwater quality. Details of the groundwater sampling activities are presented in Section 6.5. Analytical Results of the groundwater sampling activities, which are discussed in detail in Section 8, indicate that tritium was detected above the Interim Further Investigation Criterion for tritium (3,000 pCi/L) in groundwater samples collected from Monitoring Wells M, N, O, and R. In addition, tritium was detected above the laboratory detection limit in the groundwater samples collected from Monitoring Well K. Tritium was detected in the groundwater sample collected from Monitoring Well N on January 30, 2003 at a concentration above the New Jersey Groundwater Quality Criterion for tritium in Class IIA aquifers (20,000 pCi/L). Analytical results of groundwater samples collected from the Phase III monitoring wells indicated that the release of water from the Salem Generating Station Unit 1 Spent Fuel Pool had potentially migrated beyond the Styrofoam-filled Seismic Gap and into the environment. Additional investigation activities were then initiated to determine the source of the tritium detected in groundwater.

6 Remedial Investigation - March 2003 through February 2004

The remedial investigation of the release of water from the Spent Fuel Pool system was conducted between March 2003 and February 2004 in accordance with the June 2003 RIWP and the RIWP Addendum. The remedial investigation proposed in the June 2003 RIWP and the RIWP Addendum was based on the results of the three-phased initial investigation that was described in Section 5 of this report. The remedial investigation was designed to determine: 1) the source of the tritium in groundwater; 2) the extent of tritium in groundwater; 3) the fate and transport of tritium in groundwater; 4) the potential for tritium to migrate beyond the property boundaries; 5) human health and environmental risks associated with the tritium detected in groundwater; and, 6) the need for any further action.

The following sections provide the details of the remedial investigation. The results of remedial investigation activities are presented in subsequent sections of this report.

6.1 New Monitoring Well Installation – May through June 2003

Five locations were identified for the installation of additional monitoring wells. Details regarding these wells and their installation are provided in the following sections.

6.1.1 Objectives

Five additional groundwater monitoring wells (Wells S through W) and two replacement groundwater monitoring wells (Wells M and R) were installed at pre-determined locations surrounding Salem Unit 1 to evaluate the extent of tritium in groundwater, and to evaluate groundwater flow dynamics in the shallow, water-bearing unit. The locations of the monitoring wells are shown on **Figure 11**. The specific purposes for each of the monitoring wells are as follows:

- Monitoring Wells S and W were installed south and southwest of the cofferdam to characterize groundwater quality and flow conditions in an area downgradient of the Salem Generating Station Unit 1 Spent Fuel Pool between the cofferdam and the Delaware River;

- Monitoring Wells T, U, and V were installed north of the cofferdam to characterize groundwater quality and flow conditions upgradient of the cofferdam both in the shallow water-bearing unit and the Vincentown Formation; and,

- Replacements for the existing Monitoring Wells M and R were installed to allow for the collection of groundwater samples in the area of these wells from properly constructed and developed monitoring wells.

6.1.2 Field Implementation

Between May 5 and June 18, 2003, Monitoring Wells S through W were installed. In addition, existing Monitoring Wells M and R, which were originally installed as temporary wells constructed of mill-slotted Geoprobe® sample rods, were replaced with properly constructed and developed monitoring wells. The monitoring wells were installed by CT&E Environmental Services, Inc. of West Creek, New Jersey using a combination of direct-push, hollow-stem auger, and mud rotary drilling equipment. ARCADIS personnel supervised monitoring well installation activities. A summary of the well construction details for the Station monitoring wells is presented in **Table 4**. **Appendix C** presents the boring logs, well completion details, NJDEP Bureau of Water Allocation Monitoring Well Records, and Monitoring Well Certification Forms (Form B) for the wells.

Monitoring Wells S through W were constructed with two-inch diameter Schedule 40 PVC casing and well screen (0.010 slot). Well V, which is screened in the Vincentown Formation, is constructed with a six-inch diameter Schedule 40 PVC outer casing. The replacement monitoring wells for Well M and Well R were constructed of one-inch diameter Schedule 40 PVC casing and well screen (0.010 slot). A gravel pack consisting of Morie No. 1 sand was installed to a minimum of one foot above the top of the well screen. The remainder of the borehole was grouted with neat cement containing approximately five percent bentonite. The grout was installed in the annular space around the casing using a grout pump and a tremie-pipe.

Monitoring Wells S, T, U, and W were installed at various locations outside of the cofferdam. The wells were constructed with screened intervals in the hydraulic fill and riverbed deposits encountered above the Kirkwood Formation. The screened intervals for these wells range from 22 to 37 feet bgs. Monitoring Well V, installed north of the cofferdam, is constructed with a screened interval from 70 to 80 feet bgs in the deeper Vincentown Formation.

The monitoring wells were developed using a combination of surging and pumping techniques. Development of the monitoring wells was considered complete when the discharge appeared to be sediment free. Following installation, Stires Associates, P.A., a licensed New Jersey surveyor, surveyed the monitoring wells. Top of casing elevations, reported in elevations relative to plant datum, are included in **Table 4**. Monitoring Well Certification Form Bs for the wells are included in **Appendix C**. In August 2003, PSEG Nuclear, LLC conducted a separate survey to determine the relationship between plant datum and mean sea level (NAVD 1988). The results of the survey indicate that the conversion factor from plant datum to NAVD 1988 is -89.92 (i.e., to convert from plant datum to NAVD 1988 subtract 89.92 feet).

Investigation-derived waste (IDW) (i.e., drill cuttings, purge water, and decontamination materials) generated during the installation of the monitoring wells was containerized in 55-

gallon steel drums and labeled for identification. Characterization and disposal of the IDW was in accordance with Station radiological controls and waste management programs. During monitoring well installation activities, Station personnel from radiation protection monitored radioactivity in the work area to ensure the safety of project personnel and as a preliminary screening measure for IDW.

6.2 Supplemental Remedial Investigation – July through September 2003

Following installation of Monitoring Wells S through W and replacement monitoring wells for Wells M and R, an initial round of groundwater samples was collected during the weeks of June 30 and July 7, 2003. Analytical results of these groundwater samples, which are discussed in detail in Section 8, indicated that tritium was detected in the groundwater sample collected from Monitoring Well S at a concentration of 3,530,000 pCi/L. Based on the results of the groundwater sample collected from Monitoring Well S, a supplemental remedial investigation was implemented to assess the extent of tritium as indicated by this well. The details and results of the supplemental remedial investigation are presented in the following sections.

6.2.1 Objectives

In an effort to characterize groundwater in the vicinity of Monitoring Well S and to investigate the source of tritium detected in groundwater samples collected from the well, a supplemental remedial investigation was initiated. The objectives of the supplemental remedial investigation were to: 1) determine if the tritium indicated by the groundwater sample collected from Monitoring Well S had migrated to the river; 2) delineate the vertical and horizontal extent of the tritium in groundwater in the vicinity of Monitoring Well S; and 3) evaluate the potential sources of tritium in Monitoring Well S.

To achieve the objectives of the supplemental investigation, the groundwater sampling program was expanded significantly. The expanded groundwater sampling program consisted of the collection of grab groundwater samples from various depths at locations along the Delaware River, and surrounding Well S. The samples were then submitted for analysis for tritium, boron, and gamma-emitting isotopes. The groundwater sampling program designed to achieve the objectives of the investigation consisted of the collection of three proposed groundwater samples from discrete intervals in 37 proposed borings. The locations of the borings are shown on **Figure 12**. The specific purposes of the proposed borings were as follows:

- Borings 1 through 8 were advanced along the Station boundary with the Delaware River. The purpose of the borings was to evaluate concentrations of tritium and other analytes in groundwater as it approached the Delaware River.

- Borings 9 through 18 and Borings 31 through 37 were advanced within the vicinity of Station infrastructure identified as possible sources of tritium in groundwater. These potential sources include the "rad-waste" line, the Unit 1 Spent Fuel Pool, the Unit 1 refueling water storage tank, and the Unit 1 primary water storage tank.

- Borings 19 through 30 were advanced in the vicinity and downgradient of Well S to evaluate the extent of tritium indicated by groundwater samples collected from the well.

The following sections provide the details of the field implementation and analytical results obtained through the implementation of the supplemental remedial investigation.

6.2.2 Field Implementation

The supplemental remedial investigation was initiated in July 2003 following the detection of elevated concentrations of tritium in Monitoring Well S. As stated previously, the objectives of the supplemental investigation were to determine the extent of migration of the tritium, as indicated by Well S, and to assess the lateral and vertical extent and potential sources of the tritium in groundwater.

Borings were advanced at the locations shown on **Figure 12** using truck mounted Hurricane® direct-push drilling equipment to the sample target depths. The Hurricane® rig was operated by ADT Diamond Drilling, Inc. of Neptune, New Jersey. Prior to advancing the borings, Underground Services, Inc. of West Chester, Pennsylvania cleared the borings to a depth of ten feet bgs using SoftDig® technology (a vacuum excavation system). Subsurface structures, which prohibited the advancement of borings, were encountered in the locations of Borings 5, 6, 11, 16, 17, 21, and 29 through the use of SoftDig®. In these circumstances, attempts to advance the borings were abandoned.

Once cleared, groundwater samples were collected from the borings through the use of a Geoprobe® SP-15 screened point sampler advance to select target depths. Typically, the target depths for the collection of groundwater samples were as follows: 1) 11 to 15 feet bgs; 2) 21 to 25 feet bgs; and, 3) 31 to 35 feet bgs. These target intervals were chosen to evaluate groundwater at or near the water table surface, in the riverbed deposits or other sediments encountered just above the Kirkwood Formation, and some intermediate sample interval. The target sample intervals were modified in the field based on field conditions and observations, as necessary.

In several locations, the shallower target intervals (11 to 15 feet and 21 to 25 feet) yielded too little groundwater to collect a sufficient volume of water for analysis. In these locations, one-inch diameter Schedule 40 PVC temporary wells were installed to facilitate the collection of groundwater. The temporary wells were installed using two and a quarter inch diameter Geoprobe® well installation rods with an expendable point. Drilling equipment and sampling devices (e.g., the SP-15 sampler) were decontaminated between sample locations.

Maplewood Testing Services personnel (Maplewood) collected the groundwater samples using peristaltic pumps. New sample tubing was used at each sample location to prevent cross contamination between sample locations. A sufficient volume of water was collected from each sample location to analyze for tritium. Groundwater samples were collected from select borings to be analyzed for major cations and anions and gamma emitting isotopes.

The groundwater samples were submitted to the Salem Generating Station Chemistry Department (Chemistry) for initial screening for tritium and gamma-emitting isotopes. If groundwater samples did not indicate a concentration of tritium above the Station Chemistry lower level of detection (LLD), the sample was sent to the Maplewood laboratory for analysis using more sensitive equipment.

The advancement and subsequent sampling of 30 out of the 37 proposed borings was completed successfully. **Table 5** presents a summary of the details of the supplemental remedial investigation. The results of the investigation are presented in the following section.

6.2.3 Results

The laboratory analytical results for the supplemental remedial investigation are summarized in **Table 6** and are included on **Figure 13** along with the analytical results of groundwater samples collected from the Station monitoring wells. Groundwater analytical results for samples collected from the borings advanced beyond the limits of the defined plume demonstrate that there has not been a release of tritium or gamma-emitting isotopes to the river above any regulatory limits. In addition, the groundwater analytical results for samples collected from borings located at the southern and eastern limits of the supplemental investigation generally define the extent of groundwater containing tritium; however, the results of the supplemental investigation have identified an expanded area in the vicinity of Monitoring Well S with elevated levels of tritium in groundwater. This area of groundwater has been identified on **Figure 13** as an area with tritium levels above 500,000 pCi/L. Gamma-emitting isotopes were not detected at concentrations above expected background concentrations in groundwater samples collected during the supplemental investigation.

The results of the supplemental investigation were not able to complete a pathway between a potential source of primary water and Well S. Based on the distribution of tritium, and water levels observed in Monitoring Wells R and N (i.e., the hydraulic gradient in the seismic gap is from the northern to southern end), the likely source of tritium in the shallow, water-bearing unit is the southern end of the Seismic Gap, which is in direct contact with foundation soils. In order to further characterize groundwater flow within the shallow, water-bearing unit, and to establish permanent groundwater monitoring points, additional monitoring wells were required. Following completion of the supplemental investigation, the RIWP Addendum was prepared and submitted to the NJDEP-BNE presenting the details and results of remedial investigation activities completed to date. The RIWP Addendum proposed additional remedial investigation activities designed to complete the delineation of groundwater impacts, and the hydrogeologic characterization of the shallow, water-bearing unit. The proposed remedial investigation activities included the installation of 16 additional groundwater monitoring wells.

Between September 2003 and February 2004, the 16 additional groundwater monitoring wells proposed in the RIWP Addendum were installed at the Station. Initially, Monitoring Well Y, Well Z, and Wells AA through AF were installed. Following the collection and analysis of groundwater samples from these wells, and a re-evaluation of groundwater flow dynamics within the shallow, water-bearing unit, Monitoring Well AG (Shallow and Deep), Well AH (Shallow and Deep), Well AI, Well AJ, Well AL, and Well AM were installed to fill data gaps identified. Sections 6.3 and 6.4 provide the details of these monitoring well installation activities.

6.3 Monitoring Well Installation Activities – September through October 2003

Between September 22 and October 8, 2003, eight additional groundwater monitoring wells (Wells Y, Z and AA through AF) were installed at various locations adjacent to Salem Unit 1 to establish permanent groundwater monitoring locations between the Station and the Delaware River, to further characterize the extent of tritium in groundwater with concentrations above the New Jersey Groundwater Quality Criterion of 20,000 pCi/L, and to evaluate groundwater flow dynamics in the shallow, water-bearing unit. The following sections present the details of the well installation activities.

6.3.1 Objectives

The specific purposes for each of the Monitoring Wells are as follows:

- Monitoring Wells Y and Z were installed in the locations of supplemental investigation Borings 1 and 3, respectively. These wells were installed to characterize groundwater quality and flow conditions in an area downgradient of the Salem Generating Station Unit 1 Spent Fuel Pool between the cofferdam and the Delaware River;

- Monitoring Wells AA and AB were installed in the locations of supplemental investigation Borings 13 and 20, respectively. These wells were installed to characterize groundwater quality and flow conditions in an area south and southeast of Monitoring Well S, respectively;

- Monitoring Well AC was installed near the location of supplemental investigation Boring 35, as close to the Styrofoam-filled seismic gap as practical. This well was installed to characterize groundwater quality and flow conditions directly south of the Styrofoam-filled seismic gap and to the east of the Unit 1 equipment hatch;

- Monitoring Well AD was installed at a location outside of the cofferdam and within the area of groundwater containing tritium to further characterize groundwater quality and flow conditions. This well was also used for performing a pumping test to evaluate aquifer parameters;

- Monitoring Well AE was installed in the location of supplemental investigation Boring 37. This well was installed in a location east of the Salem Generating Station Unit 1 to characterize groundwater quality and flow conditions in this area; and,

- Monitoring Well AF was installed in the location of supplemental investigation Boring 18. This well was installed to characterize groundwater quality and flow conditions in an area south of the circulating water discharge pipes.

6.3.2 Field Implementation

Monitoring Wells Y, Z and AA through AF were installed by A.C. Schultes, Inc. of Woodbury Heights, New Jersey using hollow-stem auger drilling equipment. ARCADIS personnel supervised monitoring well installation activities. The locations of the monitoring wells are shown on **Figure 11.** A summary of the well construction details for the Station monitoring wells is presented in **Table 4. Appendix C** presents the boring logs, well completion details, NJDEP Bureau of Water Allocation Monitoring Well Records, and Monitoring Well Certification Forms (Form B) for the wells.

Other than Well AD, the monitoring wells were constructed with two-inch diameter Schedule 40 PVC casing and well screen (0.010 slot). Well AD was constructed with six-inch diameter Schedule 40 PVC casing and well screen (0.010 slot). A gravel pack consisting of Morie No. 1 sand was installed to a minimum of one foot above the top of the well screen. The remainder of the borehole was grouted with neat cement containing approximately five percent bentonite. The grout was installed in the annular space around the casing using a grout pump and a tremie-pipe.

Other than Well AC and Well AE, which were installed within the limits of the cofferdam, the boreholes for the wells were advanced to the depth that the Kirkwood Formation was encountered. The Kirkwood Formation was confirmed at each of the monitoring well locations through the collection of split-spoon samples. The wells were then constructed with ten-foot screened intervals exposed to the hydraulic fill and riverbed deposits directly above the Kirkwood Formation. The screened intervals for these wells ranges from a minimum top of casing depth of 26 feet bgs to a maximum bottom of screen depth of 42 feet bgs. This screened interval was chosen to monitor groundwater directly above the Kirkwood Formation in the zone of the shallow, water-bearing unit that had the potential for exhibiting the highest hydraulic conductivity (i.e., the riverbed deposits).

Well AC and Well AE, installed within the limits of the cofferdam, were advanced to the lean concrete foundation. The lean concrete was encountered at depths of 25 and 27.5 feet bgs in Well AC and Well AE, respectively. The wells were constructed with ten-foot screened intervals directly above the lean concrete. This screened interval was chosen to monitor groundwater directly above the lean concrete.

The monitoring wells were developed using a combination of surging and pumping techniques. Well AD, which was originally being considered for use during a long-term pumping test, was also developed using a chemical development agent (BMR®). Development of the monitoring wells was considered complete when the discharge appeared to be sediment free. Following installation, Stires Associates, P.A., a licensed New Jersey surveyor, surveyed the monitoring wells. IDW was handled in a manner similar to the description provided in Section 6.1.

6.4 Monitoring Well Installation Activities – January through February 2004

Following installation and development of the additional monitoring wells in September and October 2003 (Wells Y, Z and AA through AF), groundwater monitoring activities were initiated to determine the extent of delineation, and to identify data gaps that may be present in the existing monitoring well network. Groundwater monitoring activities consisted of the collection and analysis of groundwater samples from the recently installed wells and the collection and evaluation of two rounds of synoptic water levels from all of the Station monitoring wells. Based on the results of the groundwater monitoring activities, several data gaps were identified within the existing monitoring well network. As a result, eight additional monitoring wells (Wells AG-Shallow, AG-Deep, AH-Shallow, AH-Deep, AI, AJ, AL, and AM) were installed at the Salem Generating Station.

6.4.1 Objectives

The purposes for the additional monitoring wells are as follows:

- The well cluster consisting of Monitoring Wells AG-Shallow and AG-Deep was installed at the location of supplemental investigation Boring 7. The well cluster was installed to characterize groundwater quality and flow conditions in an area downgradient of the Salem Generating Station Unit 1 Spent Fuel Pool and immediately north of the circulation water discharge pipes;

- The well cluster consisting of Monitoring Wells AH-Shallow and AH-Deep was installed at the location of supplemental investigation Boring 8. The well cluster was installed to characterize groundwater quality and flow conditions in an area downgradient of the Salem Generating Station Unit 1 Spent Fuel Pool and immediately south of the circulation water discharge pipes;

- Monitoring Well AI was installed in the location of supplemental investigation Boring 9. This well was installed to further characterize groundwater quality and flow conditions within the cofferdam. Following installation, a pump test was performed on this well to evaluate aquifer parameters and potential remedial alternatives for the tritium in groundwater (e.g., capture of the tritiated water through pumping and permitted discharge);

- Monitoring Well AJ was installed outside of the cofferdam within the area of groundwater indicating relatively high concentrations of tritium. This well was used for performing a pumping test to evaluate aquifer parameters, and potentially may be incorporated into a remedial action designed to capture the groundwater containing tritium;

- Monitoring Well AL was installed in the location of supplemental investigation Boring 30. This well was installed to characterize groundwater quality and flow conditions south of the Salem Generating Station Unit 1 Spent Fuel Pool and the circulation water discharge pipes; and,

- Monitoring Well AM was installed near the location of supplemental investigation Boring 34, as close to the Styrofoam-filled seismic gap as practical. This well was installed to characterize groundwater quality and flow conditions directly south of the Styrofoam-filled seismic gap and to the west of the Unit 1 equipment hatch.

An additional monitoring well (Well AK) was proposed for the location of supplemental investigation Boring 28; however, due to plans for an additional structure to be erected at the proposed well location, the well was not installed. Other locations for the well were considered, but attempts to install the well were abandoned due to the existence of significant subsurface infrastructure in this location and the proximity of the proposed well to existing wells.

6.4.2 Field Implementation

Between January 14 and February 18, 2004, Monitoring Wells AG-Shallow, AG-Deep, AH-Shallow, AH-Deep, AI, AJ, AL, and AM were installed. Talon Drilling of West Trenton, New Jersey installed the monitoring wells using hollow-stem auger drilling equipment. ARCADIS personnel supervised monitoring well installation activities. The locations of the monitoring wells are shown on **Figure 11**. A summary of the well construction details for the Station monitoring wells is presented in **Table 4**. **Appendix C** presents the boring logs, well completion details, NJDEP Bureau of Water Allocation Monitoring Well Records, and Monitoring Well Certification Forms (Form B) for the wells.

Well clusters were installed at the locations of Well AG (Shallow and Deep) and Well AH (Shallow and Deep). The well clusters, completed within the same borehole, were constructed with screened intervals from 15 to 25 feet bgs and 30 to 40 feet bgs. The screened intervals, which were designed to provide a vertical profile of tritium immediately downgradient of the sheetpiling through which the circulation water discharge pipes penetrate, are separated by approximately four-feet of grout. The wells within each cluster are constructed of one-inch diameter Schedule 40 PVC casing and well screen (0.010 slot). A gravel pack consisting of Morie No. 1 sand, which grades to Morie No. 00 sand over the last foot, was installed to approximately one foot above the top of the well screen. The remainder of each borehole was grouted with neat cement containing approximately five percent bentonite. The grout was installed in the annular space around the casing using a grout pump and a tremie-pipe. Details regarding the installation of the remaining wells are as follows:

- Well AI and AM were installed within the limits of the cofferdam. The boreholes for these wells were advanced to the depth that lean concrete was encountered. The wells were then constructed with ten-foot screened intervals immediately above the lean concrete. These wells were constructed with four-inch diameter Schedule 40 PVC casing and well screen (0.010 slot).

- Well AJ was installed outside of the limits of the cofferdam within the area exhibiting elevated (greater than 500,000 pCi/L) levels of tritium. The borehole for well AJ was advanced to the depth that the Kirkwood Formation was encountered, which was confirmed through the collection of split-spoon samples. Well AJ was constructed with four-inch diameter Schedule 40 PVC casing and well screen (0.010 slot). The well was constructed with a 25-foot screened interval installed immediately above the Kirkwood Formation.

- Well AL, installed beyond the limits of the cofferdam and directly south of the circulation water discharge pipes, was installed to a depth of 25 feet bgs. Well AL was completed with a ten-foot screened interval designed to monitor groundwater above and downgradient of the circulation water discharge pipes. The well was constructed with two-inch diameter Schedule 40 PVC casing and well screen (0.010 slot).

A gravel pack consisting of Morie No. 1 sand was installed to a minimum of one foot above the top of the well screens. The remainder of each borehole was grouted with neat cement containing approximately five percent bentonite. The grout was installed in the annular space around the casing using a grout pump and a tremie-pipe. The monitoring wells were developed using a combination of surging and pumping techniques. Development of the monitoring wells was considered complete when the discharge appeared to be sediment free. Following installation, Stires Associates, P.A., a licensed New Jersey surveyor, surveyed the monitoring wells. IDW was handled in a manner similar to the description provided in Section 6.1.

6.5 Monitoring Well Sampling and Analysis

Groundwater monitoring activities have been ongoing since the installation of Wells K through R during Phase III of the initial Station investigation activities. Initially, groundwater samples were collected on a weekly basis. As additional monitoring wells were installed, and as a database of groundwater analytical results for the monitoring wells was generated, the monitoring well sampling program was modified. Groundwater samples are analyzed for tritium, major cations and anions, and gamma emitting isotopes. The sampling program is being adaptively managed to provide the investigational data required to meet the current investigation objectives and evaluate changes in tritium concentrations. Currently, the sampling program design for the Station monitoring wells consists of the following:

- Due to the relatively low levels of tritium (typically less than 1,000 pCi/L) historically detected in groundwater samples collected from Wells L, P, Q, T, U, and V, and the "natural" (or ambient) levels of tritium detected using low-level tritium in-growth techniques (detection limit approximately 1.5 pCi/L), these wells are currently sampled on a quarterly basis and the frequency may be reduced to semi-annual in the near future;

- Wells K, R, W, and AF are currently sampled on a monthly basis but are being evaluated for a reduced frequency based on consistent analytical results below the level of detection;

- Wells such as M, N, O, AA, AB, AC, AD, and AE, which indicate concentrations of tritium above 20,000 pCi/L, are currently sampled on a monthly basis. These wells are monitored to evaluate current plume dynamics and migration; and,

- Recently installed monitoring wells, such as Wells AG through AM, are currently sampled on a bi-weekly basis to establish an analytical history for these wells. Following development of the analytical history, the sample frequency will be modified based on similar factors as explained above.

The adaptive sampling management program is designed to ensure representative data are collected that meet the objectives of the investigation and provide the information necessary to evaluate plume dynamics and migration.

Analysis of groundwater samples collected from most of the Station Monitoring Wells has also included a single event analysis for groundwater age determination (by tritium – helium-3 age dating). As proposed in the RIWP Addendum, Tc-99 was also analyzed as a single-event analysis. The Tc-99 analysis, which was performed in lieu of iodine-129, was performed to assist in the determination of the source of the tritium. The iodine-129 analysis could not be performed due to unavailability of analysis equipment at Purdue University. Analytical results of groundwater samples collected through December 2003 are discussed in Section 8 of this report.

To minimize the influence of turbidity, groundwater samples are collected in accordance with the low-flow sampling procedure outlined in the Quality Assurance Project Plan (QAPP), which was included as an appendix to the June 2003 RIWP. The use of low-flow purging and sampling procedures results in the collection of groundwater samples from monitoring wells that are representative of groundwater conditions in the geologic formation. This is accomplished by minimizing stress on the geologic formation and minimizing disturbance of sediment that has collected in the well (*Groundwater Sampling Procedure, Low Stress (Low Flow) Purging and Sampling*, United States Environmental Protection Agency Region II, March 1998).

As outlined in the low-flow sampling standard operating procedure (SOP) provided in the QAPP, low-flow purging and sampling involves lowering a QED® Micropurge ¾-inch diameter bladder pump (model SP-¾-P) to the midpoint of the screened interval of the monitoring wells. The wells are then purged at a constant rate maintained at or below 200 milliliters per minute. The water level in the well being sampled is monitored during purging, and the pumping rate is adjusted to minimize drawdown. A properly calibrated Micropurge Basics Flow Cell Model MP20DT is used to collect field parameter measurements every five minutes from the recovered groundwater. The parameters include dissolved oxygen (DO), oxidation-reduction potential (ORP), specific conductivity, pH, and temperature.

Once the field parameters stabilize (no more than 10 percent fluctuation over three measurements), a sample is collected. The sample is collected directly from the pump discharge line, which is disconnected from the influent line of the flow-through cell to facilitate sample collection. A summary of stabilized field parameters (final readings) for groundwater samples collected from the monitoring wells is provided in **Table 7**. The field parameter measurements collected during sample collection activities indicated the following:

- Temperature ranged from 12.50 to 32.69 degrees Centigrade (°C).
- Specific conductivity ranged from 15.10 to 0.19 millisiemens per centimeter (mS/cm).
- pH ranged from 4.96 to 8.32 standard units (su).
- ORP ranged from –219 to +484 millivolts (mV).
- DO concentrations ranged from 0.04 to 8.02 milligrams per liter (mg/L).

The relatively wide range of temperatures is likely due to the influence of the facility infrastructure. The wells indicating higher temperatures are screened in the shallow, water-table aquifer in areas adjacent to subsurface structures that cause an increase in subsurface temperature (e.g., steam blow down lines).

Before sampling and between each well, all non-dedicated field equipment (e.g., submersible pumps and water-level indicators) is decontaminated following the procedures outlined in the QAPP. Purge water generated during sampling is containerized pending disposal in accordance with Station radiological controls and waste management programs.

6.6 Hydrogeologic Investigation Activities

The following sections provide the details of the site-specific hydrogeologic investigation activities detailed in the June 2003 RIWP and RIWP Addendum. These activities include the collection of groundwater elevation data from Station monitoring wells to evaluate groundwater flow conditions in the shallow, water-bearing unit; the monitoring of groundwater elevations in the Vincentown Formation to evaluate groundwater flow conditions during various points in the tide cycle; the performance of slug tests and pumping tests on various monitoring wells; the evaluation of tidal influences on the various hydrogeologic units encountered beneath the Station; and, the evaluation of a clay sample from the Kirkwood Formation to accurately characterize this unit. The results of the site-specific hydrogeologic investigation activities are presented in Section 6.

6.6.1 Evaluation of Tidal Influence

Between July 29 and August 5, 2003, data logging miniTROLL pressure transducers were installed in Monitoring Wells L, M, and W to evaluate the tidal influences of the Delaware River on water levels in the Vincentown Formation (Well L), the hydraulic fill and river bed deposits (Well W), and the structural fill within the cofferdam (Well M). The miniTROLLs were programmed to record data on 15-minute intervals throughout the period of record. In addition to the water-level information from the wells, actual tidal data from the Reedy Point, Delaware tidal station (USGS Station No. 8551910), and precipitation data from the weather station located approximately 0.9 miles east of the Salem Generating Station were obtained.

Following completion of the tests, the data were downloaded from the miniTROLLs and evaluated using Win-Situ software. The tidal data from Reedy Point and precipitation data obtained from the Station were also evaluated. An analysis of the tidal evaluation data and results are presented in Section 7.3.

6.6.2 Evaluation of Groundwater Elevations

As presented in Section 7.3, water levels in the Vincentown Formation are influenced by tidal fluctuations in the Delaware River, while water levels in the shallow, water-bearing unit are not tidally influenced. As such, the approach to evaluating groundwater elevations in these units varied. The following sections provide the details for the evaluation of groundwater elevations in these units.

6.6.2.1 Shallow, Water-Bearing Unit

To characterize groundwater flow conditions in the shallow, water-bearing unit, water level measurements were collected from the monitoring wells during six synoptic events conducted on June 26, July 28, August 15, October 14, and November 6, 2003 and February 20, 2004. A summary of the water level measurements is presented in **Table 8**. The results of the water level measurement events are discussed in Section 7.2.1.

6.6.2.2 Vincentown Formation

To characterize groundwater flow conditions in the Vincentown Formation, continuous data logging pressure transducers were installed in Well K, Well L, Well P, Well Q, and Well V from January 12 through 19, 2004. Tide data for the same time period were obtained from the tide station located at the Hope Creek Generating Station. The data obtained from these wells and the tide station were evaluated to characterize groundwater flow conditions in the Vincentown Formation during various stages of the tide in the Delaware River. The results of the groundwater elevation data for the Vincentown Formation are presented in Section 7.2.2.

6.6.2.3 Evaluation of Vertical Groundwater Gradients

To evaluate the vertical gradient between the shallow, water-bearing unit, relative groundwater elevations for the units, calculated from water level measurements obtained on June 26, July 28, August 15, October 14, and November 6, 2003, were compared. The results of this evaluation are presented in Section 7.2.3.

6.6.3 Evaluation of the Kirkwood Formation

Conflicting geologic reports suggest that the clay, confining unit that separates the riverbed deposits and hydraulic fill of the shallow, water-bearing unit from the Vincentown Formation is either the Miocene Kirkwood Formation or the Pleistocene Van Sciver Lake Bed deposits (USGS 1979 and 1999). In order to determine the relative age of the clay, confining-unit, samples of the clay obtained during the drilling of Well V were submitted to Lehigh University for pollen analysis. Results of the age determination analysis are presented in Section 7.4.

6.6.4 Aquifer Characterization

To evaluate aquifer parameters (e.g., hydraulic conductivity) for the shallow, water-bearing unit and the Vincentown Formation, slug tests and pumping tests were performed on various monitoring wells. The details of these tests are presented in the following sections.

6.6.4.1 Slug Tests

ARCADIS collected slug test data from Monitoring Wells N, O, and U in August 2003. The purpose of the slug tests was to obtain preliminary estimates of hydraulic conductivity for the structural fill encountered within the cofferdam and the hydraulic fill and riverbed deposits. Pumping tests were performed to obtain a more refined estimate of the hydraulic conductivity and other aquifer parameters for the various components of the shallow, water-bearing unit. Details regarding the proposed pumping tests are included in Section 7.4.1.

The slug tests were performed by first programming and installing an In-Situ® miniTROLL-30 PSIA pressure transducer and data logger (miniTROLL) in the test well. Programming the miniTROLLs consisted of entering the test start time (projected to be approximately 15 minutes following installation of the miniTROLLs into the test well) and data collection interval (minimum of 1.5 seconds). Following installation of the miniTROLL into the test well, the water level in the well was allowed to stabilize. (If the water level had stabilized by the time the miniTROLL was scheduled to start recording data, the slug was introduced to the well. If the water level had not stabilized, the water level was allowed to stabilize before introducing the slug.) The slug that was used for the tests is a three-foot long, one and a half (1.5) inch diameter, solid Schedule 80 PVC rod. In a two-inch diameter well, the slug will displace the water table approximately 1.7 feet (i.e., 0.27 gallons).

Upon introducing the slug to the test well to start the falling head test, the time and depth to water were recorded. During the test, the depth to water was periodically recorded to compare the water-level readings recorded by the miniTROLL. Once the water table had recovered to within 90 percent of static, the slug was removed to start the rising head test. Again, depth to water measurements and the time were recorded initially after removing the slug and periodically during the test. The test was considered complete once the water table had recovered to within 90 percent of static. The same process was repeated for each test well. An analysis of the slug test data and results are presented in Section 7.4.1.

6.6.4.2 Pumping Tests

Between January 30 and February 4, 2004, eight aquifer pumping tests were conducted on seven monitoring wells (Wells AB, AC, AD, AI, AJ, AM, and S) screened in the shallow, water-bearing unit. The tests, which consisted of both a pumping phase and a recovery phase, were performed to quantify the hydrogeologic characteristics (e.g., hydraulic conductivity) of this unit within the limits of and just south of the cofferdam.

The pumping tests were performed by first installing a variable rate two-inch submersible Grundfos® pump in the test well. A miniTROLL data logging pressure transducer was then programmed and installed in the test well. Programming the miniTROLLs consisted of entering the test start time (projected to be approximately 15 minutes following installation of the miniTROLLs into the test well) and data collection interval (logarithmic). Following installation of the miniTROLL into the test well, the water level in the well was measured and manually recorded. The pumping test was then initiated.

The wells were tested at pumping rates ranging from 0.25 to 2.0 gallons per minute (gpm). Pumping rates maintained during the pumping portion of the test were confirmed through the use of a digital flow meter and through manual flow rate calculations using a calibrated receptacle and a stopwatch. Recovery data were monitored until the water level in the well had recovered to a minimum of 85% of the static water level measured at the start of the test. The water generated during the tests was pumped directly into 55-gallon steel drums. Following completion of the tests, water in the drums was transferred to a storage tank pending characterization and disposal, which was coordinated by PSEG Nuclear, LLC personnel. Details regarding the pumping tests performed on the individual wells are provided in the following sections. Field observations made during the tests are summarized in **Table 9**. Results of the pumping tests are presented in Section 7.4.2.

6.6.4.2.1 Well AB

The pumping test conducted on Well AB consisted of a 304-minute step-drawdown test. The steps of the test were performed at the following pumping rates: 0.25 gpm; 0.5 gpm; 1.0 gpm; and, 2.0 gpm. Drawdown stabilized in the well during each pumping rate. The total volume of water recovered during the pumping test was approximately 280 gallons. The maximum drawdown observed in the well was approximately 16 feet from the static water level.

6.6.4.2.2 Well AC

The pumping test conducted on Well AC consisted of a 283-minute step-drawdown test, which was conducted concurrently with a pumping test on Well AM. The steps of the test were performed at the following pumping rates: 0.25 gpm; 0.5 gpm; and, 0.75 gpm. Drawdown stabilized in the well during the 0.25 gpm and 0.5 gpm pumping rates but the well was not able to maintain a pumping rate of 0.75 gpm. The total volume of water recovered during the pumping test was approximately 116 gallons. The maximum drawdown observed in the well was approximately 10.3 feet from the static water level.

6.6.4.2.3 Well AD

The pumping test conducted on Well AD consisted of a 331-minute step-drawdown test, which was conducted concurrently with the development of Well AJ. A noticeable effect of the development of Well AJ was observed in the water levels measured in Well AD. The steps of the test were performed at the following pumping rates: 0.25 gpm and 0.5 gpm. Drawdown stabilized in the well during the 0.25 gpm pumping rate but the well was not able to maintain a pumping rate of 0.5 gpm. The total volume of water recovered during the pumping test was approximately 85 gallons. The maximum drawdown observed in the well was approximately 17 feet from the static water level.

6.6.4.2.4 Well AI

The pumping test conducted on Well AI consisted of a 315-minute step-drawdown test. The steps of the test were performed at the following pumping rates: 0.25 gpm; 0.5 gpm; and, 0.75 gpm. Drawdown stabilized in the well during the 0.25 gpm and the 0.5 gpm pumping rates but the well was not able to maintain a pumping rate of 0.75 gpm. The total volume of water recovered during the pumping test was approximately 145 gallons. The maximum drawdown observed in the well was approximately 11.6 feet from the static water level.

6.6.4.2.5 Well AJ

The pumping test conducted on Well AJ consisted of a 275-minute step-drawdown test, which was conducted concurrently with the pumping test on Well S. The steps of the test were performed at the following pumping rates: 0.25 gpm and 0.5 gpm. Drawdown stabilized in the well during the 0.25 gpm pumping rate but the well was not able to maintain a pumping rate of 0.5 gpm. The total volume of water recovered during the pumping test was approximately 75 gallons. The maximum drawdown observed in the well was approximately 23.2 feet from the static water level.

6.6.4.2.6 Well AM

The pumping test performed on Well AM consisted of a 202-minute test that was effectively separated into two separate time frames (i.e., an initial portion and a subsequent portion). The test on Well AM was also performed concurrently with the pumping test performed on Well AC.

The initial portion of the test was performed at the following pumping rates: 0.25 gpm and 0.5 gpm. Drawdown stabilized in the well during the 0.25 gpm pumping rate but the well was not able to maintain a pumping rate of 0.5 gpm. The total volume of water recovered during the initial portion of the test was approximately 40 gallons. The maximum drawdown observed in the well during this portion was approximately 12.3 feet from the static water level.

Prior to initiating the subsequent portion of the test, the water level in the well was allowed to recover to within 90-percent of the static water level. This required approximately 90 minutes. The subsequent portion of the test on Well AM was conducted at a pumping rate of 0.33 gpm. Drawdown in the well had not stabilized at the time the subsequent portion of the test was terminated, and approximately 18 gallons of water were recovered during this portion of the test.

6.6.4.2.7 Well S

The pumping test conducted on Well S consisted of a 305-minute test, which was conducted concurrently with the pumping test on Well AJ. The pumping test was conducted at a pumping rate of 0.25 gpm. Drawdown in the well began to stabilize at this pumping rate near the end of the pumping phase of the test. The total volume of water recovered during the pumping test was approximately 77 gallons. The maximum drawdown observed in the well was approximately 20 feet from the static water level.

7 Hydrogeologic Evaluation

The following sections provide the results of the site-specific hydrogeologic investigation activities detailed in the June 2003 RIWP and RIWP Addendum, as well as a hypothesis regarding groundwater flow at the facility prior to construction of the cofferdam and other facility structures, which have had a significant impact on groundwater flow. As presented in Section 5, the site-specific hydrogeologic investigation activities included the collection of groundwater elevation data from Station monitoring wells to evaluate groundwater flow conditions in the shallow, water-bearing unit; the monitoring of groundwater elevations in the Vincentown Formation to evaluate groundwater flow conditions during various points in the tide cycle; the performance of slug tests and pumping tests on various monitoring wells; the evaluation of tidal influences on the various hydrogeologic units encountered beneath the Station; and, the evaluation of a clay sample from the Kirkwood Formation to accurately characterize this unit.

7.1 Local Hydrogeology – Pre-Facility Construction

The Station is located on the southern tip of what was once a natural bar projecting into the Delaware River. The groundwater flow conditions present in the natural bar would have been typical of those present on any island composed of unconsolidated materials. Water would move away from the axis of the bar in either direction with semi-radial flow occurring at the ends of the bar.

The area between the bar and the mainland had been formerly used as a dredge spoil area. In 1899, a timber sheetpile wall was installed around the perimeter of the bar. Over the next 50 or so years the area was used as a spoil deposit area for material obtained during the dredging of the Delaware River by the United States Army Corps of Engineers. Riprap was added to the perimeter when the timbers began to degrade (Dames & Moore February 1974, June 1977). The area landward of Artificial Island has remained a tidal marsh.

7.2 Local Hydrogeology - Current

The following sections provide the results of the site-specific hydrogeologic investigation activities. Detailed water level measurements have been collected from site monitoring wells as well as the site tidal station to determine groundwater flow directions and surface water/groundwater interactions. The results of these activities are summarized below.

7.2.1 Groundwater Flow - Shallow, Water-Bearing Unit

ARCADIS personnel performed site-wide monitoring well gauging events on June 26, July 28, August 15, October 14, and November 6, 2003 and February 20, 2004. The depth-to-water in each well was measured relative to the top of the well casing using an electronic water-level indicator. Using the gauging measurements and the surveyed top of casing elevations, groundwater elevations were calculated for each well. **Table 8** provides a summary of the groundwater elevation data.

As summarized in **Table 8**, groundwater elevations in monitoring wells screened in the shallow, water-bearing unit within the limits of the cofferdam are generally higher than groundwater elevations in monitoring wells screened in the shallow, water-bearing unit outside the limits of the cofferdam. Water-table elevations have generally decreased across the site since June 2003. A groundwater elevation contour map for the shallow, water-bearing unit based on the February 20, 2004 data is presented on **Figure 14**. Groundwater flow is generally from the center of the island (northeast of the Salem Generating Station) towards the Delaware River. Due to permeability differences between the structural fill and the hydraulic fill, groundwater is mounded within the area of the cofferdam. Groundwater flows radially outward from the cofferdam, and the observed mounding effect dissipates quickly.

7.2.2 Groundwater Flow - Vincentown Formation

As presented in Section 7.3, water levels in the Vincentown Formation, because it is a confined-unit, are tidally influenced. Water levels can vary as much as four feet per tide cycle depending on the proximity of the well to the Delaware River. To more accurately assess groundwater flow conditions in the Vincentown Formation, data logging pressure transducers were installed in Well K, Well L, Well P, Well Q, and Well V from January 12 through 19, 2004. Tide data for the same time period were obtained from the tide station located at the Hope Creek Generating Station. The water level and tide data were evaluated to characterize groundwater flow conditions during various stages of the tide cycle of the Delaware River.

Graphs of water levels for the individual wells and the tide data are presented as Figures E–1 through E–6 in **Appendix D**. The tide data was evaluated to determine the highest tide (high-high tide), the lowest tide (low-low-tide), and an intermediate high tide (low-high tide) observed during the monitoring period. Corresponding water levels in the monitoring wells were noted for these stages of the tide cycle, and groundwater elevations were calculated. Groundwater elevation contours for the high-high tide, the low-high tide, and the low-low tide are presented on **Figures 15**, **16**, and **17**, respectively.

Groundwater flow direction in the Vincentown Formation oscillates with the tides. During the high-high tide stage of the tide cycle (**Figure 15**), groundwater flow in the Vincentown Formation is perpendicular to the shoreline of the Delaware River in the west and south towards the center of Artificial Island. During the low-high tide stage of the tide cycle (**Figure 16**), an observed groundwater saddle is present between the Station and the Delaware River. Groundwater flow to the north and east of the saddle is to the south and east. Groundwater flow to the south and west of the saddle is to the north and east. During the low-low tide stage of the tide cycle (**Figure 17**), groundwater flow in the Vincentown Formation is from the center of Artificial Island towards the Delaware River.

7.2.3 Vertical Gradients

As summarized in **Table 8**, groundwater elevations in the Vincentown Formation are generally two to four feet lower than the hydraulic head in the shallow, water-bearing unit. This indicates that the potential for downward vertical migration of groundwater exists.

7.3 Tidal Evaluation Results

The results of the tidal investigation were consistent with previous tidal studies (Dames & Moore January 4, 1968). Approximately four feet of tidal response was observed in Well L (screened within the Vincentown Formation). Well W, screened within the shallow, water-bearing unit, showed a negligible tidal response. Similarly, Well M, located within the cofferdam on the west end of the Salem Unit 1 Fuel Handling Building exhibited no discernable tidal response. These tidal data indicate that the Kirkwood Aquitard effectively isolates the riverbed deposits from tidal fluctuations in the Vincentown Formation and there are no tidal influences in the aquifer where tritium has been detected. Plots depicting the tidal evaluation analyses are provided in **Appendix E**.

7.4 Evaluation of the Kirkwood Formation

Conflicting geologic reports suggest that the clay, confining unit that separates the riverbed deposits and hydraulic fill of the shallow, water-bearing unit from the Vincentown Formation is either the Miocene Kirkwood Formation or the Pleistocene Van Sciver Lake Bed deposits (USGS 1979 and 1999). In order to determine the relative age of the clay, confining-unit, samples of the clay obtained during the drilling of Well V were submitted to Lehigh University for pollen analysis. Results of the age determination analysis indicate that the clay, confining-unit is late Miocene or Pliocene in age (Yu 2003). As such, the clay, confining-unit is interpreted as the Kirkwood Formation.

7.5 Aquifer Characteristics

The following sections provide the results of the slug tests and pumping tests performed on the various monitoring wells at the Station.

7.5.1 Slug Test Results

Slug tests were performed on Monitoring Wells N, O, and U to quantify hydraulic properties in the unconfined aquifer. The field procedure followed for these tests are discussed in Section 6.6.4.1. The slug test data generated from these wells were evaluated using the Bouwer and Rice (1976) method. The primary assumptions of this analysis are: 1) the flow field is steady and laminar near the well; 2) the aquifer is homogenous and isotropic within the zone of influence; and 3) the well screen is clean.

Table 10 provides a summary of the hydraulic conductivity values estimated from the slug tests. Plots of the slug test analyses are provided in **Appendix F**. Monitoring Wells N and O are screened in the structural fill. The estimated hydraulic conductivity at Well N is between 0.09 and 0.14 ft/day. The estimated hydraulic conductivity at Well O is between 3.6 and 4.3 ft/day. The variation in hydraulic conductivity between wells reflects not only differences between soils and well construction, but also slug test procedures in general. Slug tests displace only a small volume of water in the vicinity of the well, thereby stressing only a small portion of the aquifer. The discrepancy between sampling points is not atypical. The estimated hydraulic conductivity value for Monitoring Well U screened in the riverbed deposits was 2.95 ft/day.

7.5.2 Pumping Test Results

As presented in Section 6.6.4.2, eight pumping tests were performed on seven wells (Wells AB, AC, AD, AI, AJ, AM, and S) to quantify the hydrogeologic characteristics (e.g., hydraulic conductivity) of the shallow, water-bearing unit within the limits of and just south of the cofferdam. The data collected during the pumping and recovery phases of the pumping tests were analyzed using AQTESLOV for Windows (HydroSOLVE, 1996). The results of the individual pumping tests, which are discussed in the following sections, are summarized in **Table 11**. The pumping test results indicate a range of transmissivity of 0.337 ft^2/day to 27.7 ft^2/day and hydraulic conductivities of 0.03 ft/day to 2.77 ft/day.

7.5.2.1 Well AB

Details of the analysis of the pumping and recovery phases of the step-drawdown test performed on Well AB are presented on Figures H-1 and H-2 in **Appendix G**, respectively. The average transmissivity and hydraulic conductivity calculated from the pumping data for the various steps are 27.7 ft^2/day and 2.77 ft/day, respectively. The transmissivity and hydraulic conductivity calculated from the recovery data are 22.7 ft^2/day and 2.27 ft/day, respectively.

7.5.2.2 Well AC

Details of the analysis of the pumping and recovery phases of the step-drawdown test performed on Well AC are presented on Figures H-3 and H-4 in **Appendix G**, respectively. The average transmissivity and hydraulic conductivity calculated from the pumping data for the various steps are 12.6 ft^2/day and 1.26 ft/day, respectively. The transmissivity and hydraulic conductivity calculated from the recovery data are 1.67 ft^2/day and 0.17 ft/day, respectively.

7.5.2.3 Well AD

Details of the analysis of the pumping and recovery phases of the step-drawdown test performed on Well AD are presented on Figures H-5 and H-6 in **Appendix G**, respectively. The average transmissivity and hydraulic conductivity calculated from the pumping data for the various steps are 0.942 ft^2/day and 0.09 ft/day, respectively. The transmissivity and hydraulic conductivity calculated from the recovery data are 0.937 ft^2/day and 0.09 ft/day, respectively.

7.5.2.4 Well AI

Details of the analysis of the pumping and recovery phases of the step-drawdown test performed on Well AI are presented on Figures H-7 and H-8 in **Appendix G**, respectively. The average transmissivity and hydraulic conductivity calculated from the pumping data for the various steps are 7.97 ft^2/day and 0.80 ft/day, respectively. The transmissivity and hydraulic conductivity calculated from the recovery data are 2.10 ft^2/day and 0.21 ft/day, respectively.

7.5.2.5 Well AJ

Details of the analysis of the pumping and recovery phases of the step-drawdown test performed on Well AJ are presented on Figures H-9 and H-10 in **Appendix G**, respectively. The average transmissivity and hydraulic conductivity calculated from the pumping data for the various steps are 1.73 ft^2/day and 0.09 ft/day, respectively. The transmissivity and hydraulic conductivity calculated from the recovery data are 0.56 ft^2/day and 0.03 ft/day, respectively.

7.5.2.6 Well AM

Details of the analysis of the first portion of the pumping and recovery phases of the step-drawdown test performed on Well AM are presented on Figures H-11 and H-12 in **Appendix G**, respectively. The average transmissivity and hydraulic conductivity calculated from the pumping data for the various steps are 1.40 ft^2/day and 0.14 ft/day, respectively. The transmissivity and hydraulic conductivity calculated from the recovery data are 0.572 ft^2/day and 0.06 ft/day, respectively.

Details of the analysis of the second portion of the pumping and recovery phases of the step-drawdown test performed on Well AM are presented on Figures H-13 and H-14 in **Appendix G**, respectively. The transmissivity and hydraulic conductivity calculated from the pumping data are 1.08 ft^2/day and 0.11 ft/day, respectively. The transmissivity and hydraulic conductivity calculated from the recovery data are 0.338 ft^2/day and 0.03 ft/day, respectively.

7.5.2.7 Well S

Details of the analysis of the pumping and recovery phases of the constant-rate test performed on Well S are presented on Figures H-15 and H-16 in **Appendix G**, respectively. The transmissivity and hydraulic conductivity calculated from the pumping data are 1.70 ft^2/day and 0.17 ft/day, respectively. The transmissivity and hydraulic conductivity calculated from the recovery data are 1.10 ft^2/day and 0.11 ft/day, respectively.

8 Analytical Results

In accordance with the scope of work presented in the June 2003 RIWP and the RIWP Addendum, samples have been collected from various media at the Station to determine the magnitude and extent of the release of water from the Spent Fuel Pool. Soils samples were obtained during the installation of the monitoring wells, grab groundwater samples were collected at various depths using direct push methods, and groundwater samples were collected using low flow sampling methods from the Station monitoring wells. Throughout the investigation, samples were also collected from the Spent Fuel Pool, the telltale drains, and from the various sample locations established within the facility (see **Appendix A**). Collectively, the data indicate that water from the Spent Fuel Pool leaked behind the stainless-steel liner into the obstructed telltale drains, migrated through curing cracks in the structural concrete and accumulated in the Styrofoam-filled seismic gap. Once there, the Spent Fuel Pool water, for which there is a flowpath to foundation soils, seeped into the foundation soils along the southern side of the seismic gap. This release of Spent Fuel Pool water has resulted in an area of impacted groundwater extending from the south side of the seismic gap to the circulating water discharge pipes.

The water samples collected from within the facility indicated concentrations of tritium, boron, and various gamma-emitting isotopes typical of Spent Fuel Pool water. Groundwater samples collected from outside the facility, which were analyzed for the same suite of parameters, have indicated concentrations of tritium, boron, and one slightly elevated concentration of Tc-99 that suggest that water from the Spent Fuel Pool is the probable source. The data generated during the remedial investigation, both from within the facility and groundwater samples collected from the Station monitoring wells, indicate that the removal of the mineral deposits from the telltale drains has resulted in the proper operation of the leak detection, collection and monitoring system. Analytical results of water samples collected from the drill points established within the seismic gap (DP-1 and DP-2), which initially indicated that the water in the gap was mostly Spent Fuel Pool water, have indicated decreasing concentration trends of Spent Fuel Pool constituents. As presented in **Appendix B**, the most recent water samples collected from the seismic gap indicate that the water is approximately three-percent Spent Fuel Pool water.

Additional evidence that suggests that the hydraulic head created by the blockage in the telltale drains has been removed and that Spent Fuel Pool water is no longer migrating to the seismic gap is the concentration trend of tritium in groundwater samples collected from Well AC. This well, which is installed near the contact of the southern end of the seismic gap with foundation soils, has indicated the highest concentrations of tritium and boron in groundwater and is therefore considered the source area monitoring well. Groundwater samples collected from Well AC have indicated stable concentrations of tritium indicating that the source of the tritium has been removed. Future groundwater samples collected from Well AC should indicate a decreasing trend for tritium and boron concentrations.

As stated in Section 1.1, the telltale drains are routinely monitored to ensure that mineral deposits do not accumulate and result in an additional discharge of tritium and other constituents to the seismic gap. To further ensure that the seismic gap does not provide a pathway for the migration of constituents of concern to the environment, gap drains are currently being designed and will be installed to permit detection, sampling, and draining of water (both groundwater and water from other sources) that accumulates in the seismic gaps of both Salem Units 1 and 2. The water that accumulates in the seismic gaps will be characterized by Salem Chemistry and will be handled in accordance with Station procedures. Characterization samples collected from the seismic gap drains will provide an additional line of evidence to suggest that the corrective actions taken by PSEG Nuclear, LLC have resulted in the proper functioning of the telltale drains. The drain will also provide control for residual contamination within the Unit 1 seismic gap resulting from the accumulation of Spent Fuel Pool water by permitting controlled draining of the residual contamination.

The analytical results of soil and groundwater samples collected following the initiation of the remedial investigation are presented in the following sections. Radiation protection personnel screened soil samples obtained during the installation of the Station monitoring wells for gamma-emitting isotopes. Groundwater samples collected from the monitoring wells following installation were submitted to Salem Chemistry, Maplewood and the University of Rochester for various analyses. Collectively, the data generated during the investigation was evaluated to determine that the investigation objectives were meet. As discussed previously, the investigation objectives were to determine the source, the extent, and the risk associated with the tritium in groundwater.

8.1 Soil Samples

Salem Chemistry analyzed soil samples collected from the borehole cuttings of the Station monitoring wells for gamma-emitting isotopes to determine the appropriate disposal technique based on Station procedures. The soil samples were composite samples (one sample per drum) of cuttings obtained during the monitoring well installation and vacuum excavation activities. According to PSEG, soil samples were non-detect for plant related gamma-emitting isotopes, with the exception of one of the nine soil samples collected from the cuttings of Well T (PSEG, verbal communication 2004). Well T is located to the north of the Salem Generating Station. The plant related gamma-emitting isotope identified in the Well T cuttings is not related to the tritium investigation based on the distance and orientation from the area of concern. Gamma-emitting isotopes were not detected in the other well installation soil samples.

8.2 Groundwater Samples

A total of 29 monitoring wells have been installed at various locations surrounding the Station to delineate the extent of groundwater impacts from the release of water from the Spent Fuel Pool. Numerous water quality samples have been collected from the Station monitoring wells. The groundwater samples have been analyzed to assess natural geochemistry, as well as facility-related constituents. As presented in Section 6.5, groundwater samples were initially collected on a weekly basis; however, as the number of monitoring wells increased and the analytical history of the individual monitoring wells was established, the sampling program was modified. The current monitoring plan specifies either biweekly, monthly, or quarterly sampling based upon the analytical history of each well.

Groundwater samples were submitted to Maplewood and/or Salem Chemistry for analysis for tritium, major cations and anions (sodium and boron), and gamma-emitting isotopes. A summary of the analytical results obtained from Maplewood and Salem Chemistry is presented in **Table 12**, and the analytical results for tritium are shown on **Figure 13**. As presented in Section 5.2.5, a separate set of groundwater samples was collected to perform a one-time analysis for groundwater age determination (by tritium – helium-3 ratio), dissolved gases, and Tc-99. The research analytical laboratory at the University of Rochester performed these analyses. Analytical results obtained from the University of Rochester are provided in **Appendix H**.

Analytical results for the groundwater samples, which are discussed in the following sections, were evaluated based on the water-bearing zone in which the monitoring wells are screened. The three primary water-bearing units being investigated beneath the Station are: 1) the Vincentown Formation; 2) the shallow, water-bearing unit within the limits of the cofferdam; and, 3) the shallow, water-bearing unit outside of the limits of the cofferdam.

8.2.1 Summary of Analytical Data for Wells Screened in the Vincentown Formation (Wells L, K, P, Q, and V)

With the exception of Wells K and V, analytical results of groundwater samples collected from monitoring wells screened in the Vincentown Formation do not indicate concentrations of tritium above regional background concentrations. Analytical results of groundwater samples collected from Wells K and V indicate tritium concentrations between 185 pCi/L and 1,200 pCi/L, which may be a result of tritiated water from Station activities 20 years ago that recharged to the aquifer. Analytical results of the groundwater samples obtained from the Vincentown Formation indicate concentrations of Tc-99 (0.8 pCi/L) consistent with the ambient abundance of this constituent in precipitation in the 1970s. Plant-related gamma-emitting isotopes have not been detected in groundwater samples collected from the monitoring wells screened in the Vincentown Formation. Based on groundwater flow directions and dissolved methane concentrations detected in the groundwater samples, recharge to the Vincentown Formation is likely to occur from areas north and east of the plant. The following bullets provide an evaluation of the analytical results for the individual monitoring wells screened in the Vincentown Formation.

- **Well K** – Tritium has not been detected in groundwater samples collected from Well K at concentrations above the further investigation criterion (3,000 pCi/L). A trend graph of tritium concentrations is presented on Figure I-1, in **Appendix I**. Analytical results of groundwater samples collected from Well K consistently indicate tritium concentrations between 500 and 1,200 pCi/L. The groundwater age investigation (**Appendix H**) of Well K indicates that tritiated water recharged at about 3,000 to 5,000 pCi/L approximately 19 years ago and has traveled to the upper part of the Vincentown Formation. The most likely source for this recharge is east of Well K. The level of Tc-99 is 0.8 pCi/L, consistent with post-nuclear background for the eastern United States 25 years ago.

- **Well L** – Tritium has not been detected in groundwater samples collected from Well L at concentrations above the further investigation criterion (3,000 pCi/L). Analytical results from Maplewood for groundwater samples collected from Well L are below the laboratory detection limit. Results from the University of Rochester indicate a tritium concentration of 45 pCi/L. The groundwater age analysis indicates that the water at Well L recharged about 21 years ago consistent with local precipitation 20 to 25 years ago. Groundwater at Well L is approximately the same age as groundwater at Well K, consistent with recharge that occurred 20 years ago. The absence of tritium above the laboratory detection limit suggests that there is no major pathway for tritiated water into the Vincentown Formation.

- **Well P** – Tritium has not been detected in groundwater samples collected from Well P at concentrations above the further investigation criterion (3,000 pCi/L). Analytical results from Maplewood for groundwater samples collected from Well P indicate tritium concentrations between 465 pCi/L and the laboratory detection limit. Results from the University of Rochester measured 58 pCi/L with a groundwater age of about 13 years. Well P is located downgradient, south of Salem Unit 1.

- **Well Q** – Tritium has not been detected in groundwater samples collected from Well Q at concentrations above the further investigation criteria (3,000 pCi/L). Analytical results from Maplewood for groundwater samples collected from Well Q are all below the laboratory detection limit. Low-level tritium analysis performed at the University of Rochester indicates a tritium concentration of 1.5 pCi/L, which is typical of precipitation that recharges prior to the onset of the nuclear era (ca. 1950). Elevated levels of dissolved methane in Well Q at 38 cc/kg (1.7mmol/kg) and less than solubility levels for argon and nitrogen indicate the point of recharge to be within the marshes that border the plant to the east.

- **Well V** – Tritium has not been detected in groundwater samples collected from Well V at concentrations above the further investigation criterion (3,000 pCi/L). A trend graph of tritium concentrations is presented on Figure I-8, in **Appendix I**. Analytical results from Maplewood for groundwater samples collected from Well V indicate tritium concentrations between 185 pCi/L and 549 pCi/L. Laboratory analyses from the University of Rochester were 549 pCi/L. Groundwater age dating indicates the local groundwater in Well V is 15.4 years old. Groundwater samples collected from this well indicated a dissolved methane concentration of 15.4 cc/kg methane and dissolved neon and argon concentrations below atmospheric solubility, indicating recharge from the marshes to the east.

8.2.2 Summary of Analytical Data for Wells Screened in the Shallow, Water Bearing Unit Within the Limits of the Cofferdam (Wells M, N, O, R, AC, and AE)

Analytical results of the groundwater samples indicate that tritium has been detected above 3,000 pCi/L (the Interim Further Investigation Criterion for Tritium) in groundwater samples collected from Monitoring Wells M, N, O, AC, AE and R installed within the limits of the cofferdam. Analytical results of groundwater samples collected from Well M, N, and AC have indicated concentrations of tritium above the further action criteria of 20,000 pCi/L. While they indicate elevated concentrations of tritium, they do not indicate elevated levels of plant related gamma-emitting isotopes or Tc-99. Tritium concentrations have been steady throughout the period of investigation, consistent with the hypothesis that draining of the seismic gap and the unplugging of the telltale drains has stopped the further migration of Spent Fuel Pool water out of the seismic gap. Tc-99 has been detected between 0.2 to 0.7 pCi/L, consistent with background concentrations.

- **Well M** – Prior to the replacement of Well M in May 2003, tritium concentrations detected in groundwater samples collected from Well M indicated a steady decrease in concentrations from 18,700 pCi/L on February 12, 2003 to 8,800 pCi/L on April 30, 2003. This well was replaced to conform to New Jersey well construction requirements with the new screen interval a few feet deeper than the original; the well was drilled to refusal. The analytical results of groundwater samples collected from the replacement well were initially 126,000 pCi/L, and have steadily declined to 11,400 pCi/L. Current concentrations are consistent with concentrations measured before the well was replaced. A trend graph of tritium concentrations is presented on Figure I-2, in **Appendix I**. The groundwater age dating indicates the water became isolated from the atmosphere less than 0.1years ago. Boron concentrations in Well M are between 0.222 mg/L and 0.320 mg/L, consistent with background for Artificial Island. The Tc-99 concentration for this well is 0.5 pCi/L, also consistent with background.

- **Well N** – Initial groundwater samples collected from Well N indicated concentrations of tritium above the further action criteria for tritium (20,000 pCi/L). A groundwater sample collected from Well N on January 30, 2003 indicated a concentration of tritium of 69,000 pCi/L. Concentrations detected in groundwater samples collected from Well N have declined steadily in subsequent monitoring to 6,460 pCi/L. A trend graph of tritium concentrations is presented on Figure I-3, in **Appendix I**. Boron concentrations are between 0.197 and 0.409 mg/L consistent with background levels for Artificial Island. Groundwater age dating suggests an age of about 1 year. The Tc-99 concentration in this well is 0.4 pCi/L, near the background value of 0.5 pCi/liter.

- **Well O** – Analytical results of groundwater samples collected from Well O have consistently indicated concentrations of tritium above the further investigation criterion (3,000 pCi/L) during 2003. Analytical results of groundwater samples collected from Well O by Maplewood indicate tritium concentrations between 1,220 and 13,400 pCi/L. A trend graph of tritium concentrations is presented on Figure I-4, in **Appendix I**. Concentration fluctuations have stabilized and are approximately 7,000 pCi/L. Boron concentrations have ranged from 0.071 and 0.305 mg/L consistent with background levels for Artificial Island. Groundwater age dating indicates the water is 0.22 years old. The Tc-99 concentration in this well is 0.2 pCi/L, near the background value of 0.5 pCi/liter.

- **Well R** – Analytical results of groundwater samples collected from Well R have detected concentrations of tritium at or above the further investigation criterion (3,000 pCi/L). Tritium concentrations have steadily decreased from 13,900 pCi/L on February 26, 2003 to 2,550 pCi/L on December 12, 2003. A trend graph of tritium concentrations is presented on Figure I-5, in **Appendix I**. Groundwater age dating results suggest an age of about 1.2 years. Boron concentrations have ranged from 0.229 and 0.511 mg/L consistent with background levels for Artificial Island. The Tc-99 concentration in this well is 0.4 pCi/L, near the background value of 0.5 pCi/liter.

- **Well AC** – Analytical results of groundwater samples collected from Well AC have indicated the highest concentrations of tritium in Site monitoring wells (15,000,000 pCi/L). Tritium concentrations have ranged from 10,700,000 pCi/L and 15,000,000 pCi/L. A trend graph of tritium concentrations is presented on Figure I-13, in **Appendix I**. Groundwater age dating and Tc-99 analysis have not been completed in this well because of the high levels of tritium. The boron concentration was measured between 253 mg/L and 332 mg/L. Comparison of tritium concentrations in Well AC to the Spent Fuel Pool indicates local groundwater is 5.5 to 7.5 percent Spent Fuel Pool. Comparison of the boron concentrations in Well AC to Spent Fuel Pool indicates that local groundwater is between 11 and 15 percent Spent Fuel Pool water. The difference in the percentages of Spent Fuel Pool water indicates either a 50% degradation in tritium (the water is about 12 years old) or that the plume is stratified across the well screen. Given the close proximity of Well AC to the seismic gap, the most likely interpretation is that the plume is stratified.

- **Well AE** – Analytical results of groundwater samples collected from Well AE have detected concentrations of tritium at or above the further investigation criterion (3,000 pCi/L). Tritium concentrations have ranged from 5,990 pCi/L to 16,100 pCi/L. A trend graph of tritium concentrations is presented on Figure I-15, in **Appendix I**. Groundwater age dating results suggest an age of about 0.33 years. The boron concentration was measured at 0.234 mg/L consistent with background levels for Artificial Island. The Tc-99 concentration in this well is 0.7 pCi/L, near the background value of 0.5 pCi/liter.

8.2.3 Summary of Analytical Data for Wells Screened in the Shallow, Water-Bearing Unit Outside of the Cofferdam (Wells S, T, U, V, W, Y, Z, AA, AB, AD, and AF)

The wells installed in the shallow, water-bearing unit outside of the limits of the cofferdam are screened either just above the Kirkwood Formation, or in the interval indicating the highest tritium concentrations during the Supplemental Investigation. The samples indicate that tritium has been detected above 3,000 pCi/L (the Interim Further Investigation Criterion for Tritium) in Wells S, W, AB, and AD. Wells S, AB, and AD also have indicated concentrations of tritium above the further action criteria of 20,000 pCi/L. Groundwater samples collected from these monitoring wells did not indicate concentrations of plant-related gamma-emitting isotopes. Groundwater samples collected from Well W indicated a concentration of Tc-99 above background for Artificial Island. When analyzed, there are elevated levels of boron where tritium is greater than 20,000 pCi/L. Consistent with conditions inside the cofferdam, tritium concentrations have been steady throughout the period of investigation. Tc-99 has been detected between 0.2 and 4.1 pCi/L, consistent with background concentrations or slightly higher in the groundwater sample from Well W.

- **Well S** – Groundwater samples collected from Well S detected concentrations of tritium above the further action criteria for tritium (20,000 pCi/L). Concentrations of tritium in Well S have ranged from 1,420,000 to 3,530,000 pCi/L with a declining trend over the period of investigation. A trend graph of tritium concentrations is presented on Figure I-6, in **Appendix I**. Boron concentration has been sampled once at 57.4 mg/L, indicating Spent Fuel Pool water. Comparing tritium concentrations in local groundwater to SFP indicate 0.7% to 1.7% Spent

Fuel Pool water. The boron sample indicates a composition of about 2.5% Spent Fuel Pool water. This reduced tritium concentration indicates an age of approximately 6.9 years. Groundwater age dating comparing helium to tritium ratios suggests an age of about 0.7 years. No plant related gamma-emitting isotopes have been detected in Well S. The Tc-99 concentration in this well is 0.5 pCi/L, equal to the background value. Groundwater samples collected from Well S were also analyzed for strontium-89 and strontium-90. Analytical results of these groundwater samples did not indicate concentrations of these constituents above the laboratory detection limit.

- **Well T** – Groundwater samples collected from Well T have been below the further investigation criteria for tritium (3,000 pCi/L). All samples sent to Maplewood were non-detect for tritium while the one sample sent to the University of Rochester detected 257 pCi/L. Boron concentrations ranged from 0.601 mg/L to 0.680 mg/L consistent with background levels for Artificial Island. Groundwater age dating suggests an age of about 1.6 years. No plant related gamma-emitting isotopes have been detected in Well T. The Tc-99 concentration in this well is 0.7 pCi/L, slightly above the background value of 0.5 pCi/L.

- **Well U** – Groundwater samples collected from Well U been below the further investigation criterion for tritium (3,000 pCi/L). Tritium results from samples sent to Maplewood ranged from non-detect to 203 pCi/L while the one sample sent to the University of Rochester detected 78 pCi/L. A trend graph of tritium concentrations is presented on Figure I-7, in **Appendix I**. Boron concentrations ranged from 0.341 mg/L to 0.421 mg/L consistent with background for Artificial Island. Groundwater age dating suggests an age of about 4.1 years. No plant related gamma-emitting isotopes have been detected in Well U. The Tc-99 concentration in this well is 0.5 pCi/L, equal to the background value.

- **Well W** – Groundwater samples collected from Well W have been above the further investigation criterion for tritium (3,000 pCi/L). Tritium results from samples ranged from 6,010 pCi/L to 15,500 pCi/L. The one sample sent to the University of Rochester detected 13,062 pCi/L. A trend graph of tritium concentrations is presented on Figure I-9, in **Appendix I**. Boron concentrations range from 0.464 mg/L to 0.591 mg/L consistent with background levels for Artificial Island. The groundwater age determination for a groundwater sample collected in July 2003 had a significant uncertainty likely related to the monitoring well installation. The groundwater age determination for a groundwater sample collected in November 2003 indicated an age of 4.1 years. No plant related gamma-emitting isotopes have been detected in Well U. The Tc-99 concentration in this well is 4.1 pCi/L, slightly above the expected background value.

- **Well Y** – Groundwater samples collected from Well Y have been below the further investigation criterion for tritium (3,000 pCi/L). Tritium results from samples sent to Maplewood have been non-detect. The boron concentration was measured at 0.822 mg/L, consistent with background levels for Artificial Island. The well was not sampled for groundwater age dating or Tc-99. No plant related gamma-emitting isotopes have been detected in Well Y.

- **Well Z** – Groundwater samples collected from Well Z have been below the further investigation criterion for tritium (3,000 pCi/L). Tritium results from samples sent to Maplewood ranged from non-detect to 729 pCi/L while the one sample sent to the University of Rochester detected 729 pCi/L. A trend graph of tritium concentrations is presented on Figure I-10, in **Appendix I**. The boron concentration was 0.498 mg/L, which is consistent with the background level for Artificial Island. Groundwater age dating suggests an age of about 3.2 years. No plant related gamma-emitting isotopes have been detected in Well U. The Tc-99 concentration of the groundwater sample collected from this well is 0.4 pCi/L, slightly below the background value of 0.5 pCi/L.

- **Well AA** – Tritium concentrations in groundwater samples collected from Monitoring Well AA have been below the further investigation criterion for tritium (3,000 pCi/L). Tritium results from samples sent to Maplewood ranged from 613 pCi/L to 785 pCi/L while the one sample sent to the University of Rochester detected 734 pCi/L. A trend graph of tritium concentrations is presented on Figure I-11, in **Appendix I**. The boron concentration was 0.247 mg/L, which is consistent with the background level for Artificial Island. Groundwater age dating suggests an age of about 2.1 years. No plant related gamma-emitting isotopes have been detected in Well AA. The Tc-99 concentration of the groundwater sample collected from this well is 0.5 pCi/L, equal to the background value.

- **Well AB** – Groundwater samples collected from Well AB detected concentrations of tritium above the further action criterion for tritium (20,000 pCi/L). Concentrations of tritium detected in groundwater samples collected from Well AB have ranged from 280,000 to 409,000 pCi/L. A trend graph of tritium concentrations is presented on Figure I-12, in **Appendix I**. Boron analysis has not been performed on groundwater samples collected from this well due to elevated tritium results. Comparing tritium concentrations in local groundwater to Spent Fuel Pool indicate that the groundwater is 0.14% to 0.20% Spent Fuel Pool water. Groundwater age dating suggests an age of about 1.38 years. No plant related gamma-emitting isotopes have been detected in Well AB. The Tc-99 concentration in the groundwater sample collected from this well is 0.4 pCi/L, slightly below the background value of 0.5 pCi/L.

- **Well AD** – Groundwater samples collected from Well AD detected concentrations of tritium above the further action criterion for tritium (20,000 pCi/L). Concentrations of tritium detected in groundwater samples collected from Well AD have ranged from 220,000 to 487,000 pCi/L. A trend graph of tritium concentrations is presented on Figure I-1, in **Appendix I**. Boron analysis has not been performed on groundwater samples collected from this well due to elevated tritium results. Comparing tritium concentrations in local groundwater to Spent Fuel Pool indicates that 0.11% to 0.24% of the ground water is Spent Fuel Pool water. Water samples from this well were not analyzed for age dating or Tc-99. No plant related gamma-emitting isotopes have been detected in Well AD.

- **Well AF** – Groundwater samples collected from Well AF did not detect tritium concentrations above the further investigation criterion for tritium (3,000 pCi/L). Concentrations in Well AF have ranged from non-detect to 330 pCi/L. The analytical results of the low-level tritium analysis performed at the University of Rochester indicated a tritium concentration of 245 pCi/L. The groundwater age determination for the sample collected from Well AF indicates an age of approximately 10 years. A trend graph of tritium concentrations is presented on Figure I-14, in **Appendix I**. Boron has been detected at concentrations between 0.380 mg/L and 0.429 mg/L consistent with background levels for Artificial Island. The Tc-99 concentration detected in the groundwater sample collected in this well is consistent with regional background concentrations. No plant related gamma-emitting isotopes have been detected in Well AF.

8.3 Delaware River Tritium Concentrations

Based on the analytical results of groundwater samples collected from the monitoring wells placed near the Station boundary with the Delaware River, the tritium detected in the shallow, water-bearing unit is not releasing to the Delaware River at concentrations that could violate any exiting standard.

A groundwater model is being developed that will provide a quantitative assurance that the tritium in the shallow, water-bearing unit will continue to meet all off-site regulatory standards for tritium. Sampling and analysis of the Delaware River in the vicinity of Salem is routinely conducted and reported under the Radiological Environmental Monitoring Program ("REMP"). A surface water sampling program was evaluated and determined to be impracticable. The tritium contamination in the shallow, water-bearing unit would not be expected to be discernable in the Delaware River even if a release occurred because:

1. Based on the location and extent of the plume as determined by site sampling, tritium concentrations from the shallow, water-bearing unit would not be detected in the Delaware River;

2. The ambient tritium levels fluctuate in the environment as shown in the historical Radiological Environmental Monitoring Reports (RERRs) submitted annually. There is no viable method of distinguishing low level ambient tritium in the Delaware River from any shallow, water-bearing unit discharge;

3. The volume, velocity, and bi-directional tidal flow of the Delaware River prevent making generalizations regarding the transport of tritium in the river and distinguishing between potential sources including routine permitted discharges; and,

4. Analyses conducted on shallow, water-bearing unit show the only facility related parameter to be tritium; no plant related gamma emitters have been detected. Therefore, there are no "tracer" parameters that can be used to define the source of any tritium detected; and,

5. Delaware River sediment sampling would not provide any useful data regarding a potential release of tritium from the shallow, water-bearing unit as tritium is water and will not adsorb to soil or sediment.

Based on these evaluations, no sampling of the Delaware River water or sediment for tritium has been conducted for this remedial investigation. A mathematical model of the potential concentrations in the Delaware River will be developed to provide the information for adapting the remedial action plan to ensure there is no release to the Delaware River above a regulatory standard as well as validating that there is no significant impact to the environment. The model will serve as the basis for evaluating tritium mass flux to the Delaware River and to assess remedial system performance.

The groundwater flow model will be constructed using the computer program MODFLOW, a publicly available groundwater flow simulation program developed by the USGS. MODFLOW is thoroughly documented, widely used by consultants, government agencies and researchers, and is consistently accepted in regulatory proceedings. The hydrogeologic studies conducted and samples collected for the tritium investigation will be used to define model parameters.

A solute transport model will be used to simulate the movement of tritium considering the processes advection, dispersion, and radioactive decay. The solute transport modeling will be performed using MT3D, a three-dimensional solute transport program developed by the US Environmental Protection Agency. MT3D is used in conjunction with MODFLOW, thereby providing a seamless transition from the groundwater flow model to the solute transport modeling. Similar to MODFLOW, MT3D is thoroughly documented and routinely used in regulatory proceeding.

9 Fate and Transport Analysis

Shallow groundwater in the vicinity of the Station has been impacted by a release of water from the Spent Fuel Pool. The pathway from the building to the environment cannot be documented with absolute certainty; however, site evidence indicates the seismic gap between the Salem Unit 1 Fuel Handling Building and Auxiliary Building is the primary release point. The origin of the water in the seismic gap is the Spent Fuel Pool and the pathway from the Spent Fuel Pool is discussed in Section 5. This release has resulted in a plume of boron and tritium extending south-southwest from this point-of-origin as shown on Figure 13; no other contaminates of significance have been detected in the affected area. The fate and transport of this plume is assessed in this section to determine flow pathways and the rate of migration.

Quantification of solute migration requires specification of various transport parameters and processes that control the rate, movement, mixing, sorption, and degradation of a contaminant in the subsurface. Advection defines the process of contaminant migration due to the movement of groundwater. Dispersion accounts for the spreading and mixing of the constituent due to heterogeneities and non-ideal flow paths in the soil that cause variations in the groundwater velocity as well as Fickian diffusion driven by concentration gradients. Sorption refers to the partitioning of a contaminant between the liquid and solid phases of the aquifer. Degradation is the mass decay of a contaminant as a result of physical, chemical, and biological activity within the aquifer. Each of these processes and their effect on the movement of site related constituents along flow pathways are summarized in the following sections.

9.1 Constituent Pathways – Advective Water Movement

Water-level measurements taken in monitoring wells distributed spatially across the site and distributed within several depth intervals provide the necessary information to describe the direction of groundwater movement. These water-level measurements are combined with effective porosity and hydraulic conductivity measurements to determine the rate or speed of groundwater movement. In general, water-level measurements are used to define the slope of the water table (gradient) and direction of movement; groundwater moves down the slope or gradient from high water table elevations to lower water table elevations. Water level elevations, hydraulic gradients, and groundwater flow directions for the shallow, water-bearing unit are presented on **Figure 14**. Based upon both water levels and constituent concentrations, the primary flow pathways are away from the seismic gap toward the south-southwest. Along individual flow paths there is a decrease in both water-level elevations and concentrations of isotopes of interest.

The movement of a solute with the groundwater, or advective transport, can be computed using Darcy's Law. Darcy's Law is written as follows:

$$q = K i \qquad (1)$$

where, q is the Darcian flux ($ft^3/day/ft^2$ or ft/day), K is the hydraulic conductivity (ft/day), and i is the hydraulic gradient (ft/ft). Aquifer testing at the Site (Section 7.5) has determined that the mean hydraulic conductivity of the soils affected by tritium to be approximately 0.4 ft/day. The average hydraulic gradients are approximately 0.008 ft/ft and 0.004 ft/ft inside and outside the cofferdam, respectively. Therefore, the specific discharge of groundwater inside and outside the cofferdam is 0.0032 ft/day and 0.0016 ft/day, respectively. Since water can only move through the pore spaces, these values are not the velocities at which groundwater is moving. The average linear velocity of groundwater is higher as water moves only through the voids or pore spaces of the soil:

$$v = {}^{q}\!/_{\theta_e} \qquad (2)$$

where v is the velocity (ft/day) and θ_e is the effective porosity (ft^3/ft^3). The effective porosity for the unconsolidated sediments at the site was assumed to be 0.20. This value is consistent with estimates developed by the USEPA (1989) that indicate most medium to coarse-grained soils (Unified Soil Classification System textural groups GW, GP, GM, GC, SW, SP, SM, and SC) have an effective porosity of approximately 0.2. The groundwater velocity inside and outside the cofferdam computed from the average flow rates and an effective porosity of 0.2, are 5.8 ft/yr (0.0032/0.2*365) and 2.9 ft/yr (0.0016/0.2*365), respectively. Applying the higher of these velocities over the groundwater pathway between the seismic gap and the 500,000 pCi/L contour, indicates the plume is 31 years old. This travel time or age of the tritium plume is inconsistent with facility data, other observed, modeled, and calculated data, and it is longer than the facility has been in operation. These slow travel velocities indicate that the hydraulic conductivity value from the pumping tests are biased low; the use of drawdown data in the pumping well as the only observation point for each test precludes assessment of well efficiency which increase drawdown in the pumping well. The pumping test data and analysis did provide accurate information concerning sustained yield for the design of a groundwater containment system.

9.2 Water Balance Estimate of Groundwater Velocities

To assess this discrepancy and develop a better estimate of groundwater velocities and travel times, an alternative method based upon continuity and a water balance approach, was used to estimate the hydraulic conductivity and groundwater velocities. The plume and the impacted groundwater are located in a hydrologically isolated portion of the facility; the source for all of the groundwater within the plume, originates from within the plume. Therefore, if we know how much water is moving along a flow path (the recharge rate), the length of the flow path (seismic gap to the 500,000 pCi/L isopleth), the saturated thickness of the aquifer (about 15 feet within the cofferdam and 35 feet outside the cofferdam), and hydraulic gradient (the water table slope is 0.008 inside the cofferdam and 0.004 outside the cofferdam), an effective or mean hydraulic conductivity can be computed.

Figure 18 illustrates the idealized flow path from the seismic gap to the 500,000 pCi/L isopleth. The total flow per unit width at a point along this pathline is:

$$q' = K\,i\,b \qquad (3)$$

where b is the saturated aquifer thickness. Equation (3) is also equal to the cumulative recharge upgradient from a point where (3) is applied:

$$q' = L\,N \qquad (4)$$

where N is the recharge and L is the upgradient flow path length. Recharge or percolation is the flux to the water table; a portion of precipitation impacts the land surface, a portion runs off, the remainder infiltrates into the groundwater, and the fraction that infiltrates which does not become evapotranspiration is recharge. The total length of a flow path from the seismic gap to the 500,000 pCi/L isopleth is approximately 186 feet, 102 feet from the seismic gap to the limit of the cofferdam (section 1), with an additional 84 feet from the limit of the cofferdam to the 500,000 pCi/L contour (section 2). If we equate equations (3) and (4), assume a recharge rate of 8 in/year, and apply them to section 1 of the flowpath on **Figure 18**, we can write the following:

$$K_1\,i_1\,b_1 = L_1\,N$$

$$K_1 \times 0.008\,{}^{ft}\!/_{ft} \times 15\,ft = 102\,ft \times 0.67\,{}^{ft}\!/_{yr}$$

$$K_1 = \frac{102 \times 0.67}{0.008 \times 15} = 570\,{}^{ft}\!/_{yr} \; or \; 1.6\,{}^{ft}\!/_{day}$$

In summary, if the percolation rate is approximately 8 in/yr, the effective hydraulic conductivity of the saturated soils above the cofferdam is about 1.6 ft/day. Similarly, if the recharge rate were 16 in/yr, the effective hydraulic conductivity of the saturated soils above the cofferdam would be double or about 3.2 ft/day.

Repeating these calculations for Section 2 of the flowpath on **Figure 18**, and noting that the total amount of water through this section also includes the flow through section 1, we can write the following:

$$K_2\,i_2\,b_2 = L_1\,N + L_2\,N = N\left(L_1 + L_2\right)$$

$$K_2 \times 0.004 \, ft/ft \times 35\, ft = 0.67\, ft/yr \, (102\, ft + 84\, ft)$$

$$K_2 = \frac{186 \times 0.67}{0.004 \times 35} = 890\, ft/yr \; or \; 2.4\, ft/day$$

In summary, if the percolation rate is approximately 8 in/yr, the effective hydraulic conductivity of the saturated soils outside the cofferdam is about 2.4 ft/day. Similarly, if the recharge rate were 16 in/yr, the effective hydraulic conductivity of the saturated soils outside the cofferdam would be double or 4.8 ft/day.

Consistent with Section 9.1 above, groundwater velocities were computed using these alternative hydraulic conductivity values developed using equations (3) and (4). The groundwater velocity inside and outside the cofferdam computed from the average hydraulic gradients, an effective porosity of 0.2, and a recharge rate of 8 in/yr are 23.4 ft/yr (1.6*0.008/0.2*365) and 17.5 ft/yr (2.4*0.004/0.2*365), respectively. Similarly, if the recharge rate were 16 in/yr, then the groundwater velocity inside and outside the cofferdam would be 46.7 ft/yr (3.2*0.008/0.2*365) and 35.0 ft/yr (4.8*0.004/0.2*365), respectively. Applying these velocities over the groundwater pathway between the seismic gap and the 500,000 pCi/L contour, the plume is between 4.6 and 9.2 years old. This estimated age of the tritium plume is consistent with general hydrogeologic conditions and available facility operation records, and groundwater age results.

9.3 Sorptive Processes

The term sorption refers to the removal of a solute from solution through association with a solid surface. This attraction between a soil surface and a solute can result from a number of forces. The effects of these forces or processes are commonly described by sorption isotherms. These isotherms assume that when a solution contacts a solid, the solute will tend to transfer from liquid to solid until the concentration of solute in solution is in equilibrium with the soil concentration. These processes, especially for inorganic compounds, tend to be pH dependent, not always completely irreversible, and site specific. With respect to the constituents found in groundwater at the Salem site, this process has no effect on the movement of tritiated water and only a minor effect on the movement of boron; however, this process is important to understanding why the other dissolved constituents identified in the seismic gap have not been found in Site monitoring wells.

Table 1 summarizes the complete list of constituents found in the Spent Fuel Pool and potentially in the seismic gap and adjacent groundwater as well as their sorptive characteristics to soil. Columns 4 and 5 summarize the range in literature reported distribution coefficients. The distribution coefficient (K_d) is defined as follows:

$$K_d = \frac{Soil\,Concentration}{Dissolved\,Concentration} \quad (5)$$

Therefore, the higher the distribution coefficient, the more strongly a constituent will stick (i.e., adsorb and absorb) to soils. The range in values reported in **Table 1** is most strongly correlated to pH and amount of clay or fines in site soils. Solutes dissolved in low pH water in soils without fine materials will tend to adsorb to soils and have K_d in the lower reported range. Solutes dissolved in neutral pH water (consistent with site conditions) with a quantifiable fraction of fine sediments (the site soils have a minimum of 5% silt and clay) will tend not to adsorb to soils and have K_d in the lower reported range. This process of exchange and interaction between solute and soil will also cause solutes to move slower than the groundwater. This ratio of the groundwater velocity to the solute velocity is caused the retardation factor. The retardation factor can be computed from the distribution coefficient using the following equation:

$$R_f = 1 + \frac{\rho_b K_d}{\theta_e} \quad (6)$$

where ρ_b is the bulk density. Gamma emitting isotopes are absent from site monitoring wells because they have adsorbed to soils near the seismic gap and are moving at only a fraction of the speed of the tritium and boron.

9.4 Degradation

With the exception of boron, all site related constituents degrade. **Table 1** summarizes the half-lives for each constituent.

9.5 Dispersion

Dispersion is the process whereby contaminants spread over a greater region than would be predicted solely from the average linear groundwater velocity. Dispersion occurs at multiple scales. The primary cause of dispersion is variations in groundwater velocity, on a microscale by variations in pore size and on a macroscale by variations in hydraulic conductivity. The hydrodynamic dispersion tensor is complex. For isotropic media, the dispersion coefficient written to incorporate molecular diffusion (described by Fick's Law), is calculated as follows:

$$D_c = \alpha_d v + D \quad (7)$$

where D_c is the dispersion coefficient $[L^2/T]$, α_d is the dispersivity [L], v is the groundwater velocity [L/T], and D the molecular diffusion coefficient $[L^2/T]$.

While the general process of dispersion is understood, the dispersivity of a formation is not easily measured or quantified at the field scale. Therefore, as dispersion is related to porewater velocities, plume travel distance is the single most important factor that can be correlated to dispersivity. This general relationship is best illustrated in a figure developed by Gelhar et al. (1992). If we consider Figure 19, the scale of the plume is about 180 ft (60 m), which corresponds to a longitudinal dispersivity of approximately 3.3 m. The groundwater velocity is about 9 m/yr, and molecular diffusion for most common ions is on the order of 2×10^{-9} m^2/s (or 0.0631 m^2/yr). Substituting these values into equation (7), yields:

$$D_c = 3.3m \times 9 m/_{yr} + 0.0631 m^2/_{yr}$$

$$D_c = 29.7 m^2/_{yr} + 0.0631 m^2/_{yr}$$

Comparison of the above two terms, indicates that movement of the primary constituents at the site (tritium and boron) is primarily an advectively driven process as the first term is approximately 500 times larger than the second. The site data also reflects this, with slightly elevated levels of tritium extending approximately 75 feet downgradient of the leading edge of the center of mass of the plume.

9.6 Tritium Age Dating and Groundwater Travel Time

The most effective use of groundwater age dating in transport analyses is in the determination of the vertical component of groundwater velocity and the recharge rate to the aquifer. The shallow wells inside of the cofferdam (Wells N, O, M, and AE) have effectively "zero tritium-^{3}He ages" because of the shallow depth of the wells below the water table, the screened interval's exposure to air (i.e., interval above the water table) and the introduction of atmospheric gases during monitoring well installation activities. The wells outside of the cofferdams (Wells S, AA, and AB) that are directly downgradient from the seismic gap have ages from which one can estimate recharge. For Well S, the calculation of age determination has tritium moving over the top of the cofferdam (at –13 feet and zero tritium-^{3}He age) to the mid-point of the screened interval at S (-18 feet) or 5 vertical feet in 0.7 years (7 +/- 2 feet/yr). This change in vertical elevation for the tritium plume is equivalent to a recharge of 16 in/yr (assumes a porosity of 0.2). A similar calculation for Well AB, as the plume moves from –13 feet at the cofferdam to –23 feet at the well, yields a recharge rate of 17 in/yr (vertical movement of 10 feet in 1.4 years). A similar calculation can be made for Well AA. Because AA is not tritium contaminated, the flow line did not originate at the lean concrete at the top of the cofferdam but rather at the seasonally low water table in the vicinity of well S. The "clock" for this age system is not set until approximately 3 feet below the water table. Thus, we have the flow from –3 feet to –18 feet (mid-point of screen) in 2.1 years or 7 feet/yr, equal to 16 in/yr of recharge. The agreement in recharge estimates for the three wells is somewhat fortuitous but it can reasonably be characterized as 16 +/- 4 in/yr or about 40% of annual precipitation. This estimate of 40% is consistent with other flow systems that have limited evapotransporation (i.e., no grass or trees). Other wells that are screened at the 35-foot level (Wells Z, U, T, and W) have ages of about 3 to 4 years for 20-25 feet of vertical travel, equal to a vertical velocity of 6 to 8 feet/yr. The recharge estimate can then be used in the water balance calculation (Section 9.2) to estimate horizontal transport. The calculations based on groundwater ages agree with the estimates based on the physical properties of the structural fill (e.g., aquifer pumping tests) and water balance calculations.

10 Health and Environmental Risk Assessment

The principal radionuclide of concern for this remedial investigation is tritium in shallow groundwater adjacent to Salem Generating Station Unit 1. To date, a completed exposure pathway to humans from tritium in shallow groundwater has not been established, nor is there any evidence that significant exposures of biota have occurred. However, since the remedial investigation is continuing, there is a still a possibility that findings might indicate that significant amounts of tritium have migrated to off-site locations, or could be expected to do so, under certain conditions. Therefore, there should be a conceptual approach that outlines the methodology that will be followed in assessing potential impacts on human health and the environment from any such occurrence. This conceptual approach is presented in Section 6.3, following brief discussions of on-site and off-site environmental data for tritium.

10.1 On-Site Environmental Data for Tritium

Concentrations of tritium in groundwater samples taken over time from monitoring wells on the Salem Site provide the most important data set for characterizing the inventory of tritium that could potentially migrate to off-site locations. If transport from shallow groundwater to off-site locations were observed or assumed to occur, data from monitoring wells would be used as input to an analysis of environmental transport to locations where humans or biota could be exposed. Data on concentrations over time at various on-site locations could be used to calibrate a dynamic environmental transport model to project future releases. Knowledge of the age of tritium in on-site environmental samples is needed to determine if releases occurred many years ago or are recent and, perhaps, continuing at the present time.

10.2 Off-Site Environmental Data for Tritium

The program of off-site environmental monitoring at the Salem Station has not detected tritium in environmental media or biota at concentrations above the lower limit of detection in routine sampling procedures. Routine off-site environmental monitoring data will continue to be examined for indications that tritium in shallow groundwater at the Salem Station has migrated beyond the Station boundary.

In evaluating environmental monitoring data, it is important to recognize that all environmental media and living organisms contain low levels of tritium from two sources that are unrelated to operations at the Salem Station: (1) naturally occurring tritium that is continually produced by interactions of cosmic radiation with constituents of the earth's atmosphere, and (2) tritium that was injected into the atmosphere during the period of above-ground testing of nuclear weapons that ended in the early 1960s. Tritium from those sources occurs as tritiated water, which is transported in the environment and incorporated into tissues of all organisms by the natural movement of water. This remedial investigation is concerned only with uncontrolled or unexpected releases of tritium to off-site locations, but not with levels due to natural production in the atmosphere and residual contamination from nuclear-weapons testing.

10.3 Methodology for Health and Environmental Risk Assessment

The following sections discuss the steps to be taken to perform a health and environmental risk assessment if tritium were released, or assumed to be released, to locations beyond the site boundary under uncontrolled or unpermitted conditions.

10.3.1 Identification of Exposure Pathways

Since tritium in the environment normally is in the form of tritiated water, exposures of humans and biota occur as a result of intakes of contaminated water by various pathways. When tritium is found in groundwater or surface water, the most important pathway of exposure of humans often is direct consumption of tritium in drinking water obtained from a contaminated source. Consumption of contaminated plant and animal products, including fish, also can be important exposure pathways for humans. A third potential exposure pathway for humans is inhalation and skin absorption of tritiated water vapor. This pathway can be important if an on-site release of tritiated water vapor occurs and airborne tritium is transported to off-site receptor locations. External exposure to tritium is not a concern, because tritium emits only very low-energy electrons (beta particles) that cannot penetrate the outer dead layer of skin.

Doses and risks to humans occur only when there is a completed exposure pathway. If no exposure pathways are known to exist, an assumption that humans are being exposed to known sources of tritium in the environment (either on-site or off-site) can be made for the purpose of obtaining bounding estimates of potential doses and risks. For example, direct consumption of tritium in shallow groundwater at the Salem site can be assumed, even though that pathway is precluded by institutional controls that are maintained at the site. Such bounding analyses are hypothetical, but they are useful in evaluating the potential importance of assumed levels of environmental contamination. However, it is important to emphasize that calculated doses are credible only if there is a completed exposure pathway.

Doses to aquatic and terrestrial biota due to tritium in the environment normally can be estimated on the basis of an assumption that organisms reside in a contaminated medium (e.g., surface water) and that concentrations of tritium in tissues of organisms are the same as concentrations of tritium in water in the medium. Since tritium in the environment behaves in the same way as water, tritium is not concentrated in tissues of organisms compared with levels in contaminated environmental media.

10.3.2 Identification and Characterization of Potentially Exposed Individuals and Biota

A realistic assessment of doses and risks to humans requires knowledge of the locations and living habits of potentially exposed individuals. However, for purposes of a bounding analysis, it is often assumed that humans are exposed at locations of highest concentrations in the environment beyond the site boundary, even though there may be no receptors at those locations at the present time. Assumptions about locations and exposures of potential receptors can be based on readily available demographic information on the local population, augmented by standard assumptions about living habits of typical members of the general public. The level of detail in characterizing potential receptors should be commensurate with expected levels of environmental contamination and associated doses and risks.

A detailed characterization of local flora and fauna is not required in evaluating impacts of tritium (and other radionuclides) on biota, because current guidance on protection of biota is based on assumptions about the effects of ionizing radiation on the most sensitive species of aquatic animals and terrestrial plants and animals. Thus, an assessment of potential impacts on biota can be based on an assumption that all organisms are located where the highest concentrations of tritium in environmental media occur.

10.3.3 Approach to Calculation of Doses to Humans and Comparisons with Applicable Standards

On the basis of estimated concentrations of tritium in environmental media, including their dependence on time, and assumptions about exposure pathways, it is a straightforward procedure to estimate radiation doses to humans. In general, dose is calculated as the product of an activity concentration of tritium in a material (air, water, or foodstuff) used by humans, an assumed intake of that material by ingestion, inhalation, or skin absorption, and estimated doses per unit activity intake of tritium by each route.

Using the drinking water pathway as an example, the dose to an exposed individual is calculated as the product of (1) the concentration of tritium in the source of water being consumed, (2) the quantity of water consumed over the period of concern, and (3) the dose per unit activity intake of tritium by ingestion. The first factor is based on environmental measurements or projections of future contamination; the second factor is an appropriate assumption for the exposure pathway of concern, such as a consumption rate of 2 liters (L) per day of drinking water; and the third factor is a standard value calculated by the International Commission on Radiological Protection (ICRP), with an appropriate modification that takes into account the biological effectiveness of beta particles emitted in tritium decay. An example dose calculation for tritium in drinking water is given in **Appendix I** (Kocher 2003).

A number of regulatory standards are applicable to control of exposures to tritium at the Salem Station. In regard to releases of tritium beyond the Station boundary, the applicable standards include (1) the NRC's radiation protection standards for the public in 10 CFR Part 20, which specify limits on concentrations of tritium (and other radionuclides) in air or water at the boundary and also specify that annual doses to individual members of the public from airborne releases shall comply with standards established by the EPA under the Clean Air Act in 40 CFR Part 61, and (2) the EPA's uranium fuel-cycle standards in 40 CFR Part 190, which specify limits on annual doses to individual members of the public from all release and exposure pathways combined. The two EPA standards differ from the NRC standards in 10 CFR Part 20 in that they apply at locations where members of the public are exposed, rather than at the Station boundary. The standard for airborne releases of tritium in EPA's Clean Air Act standards is a limit on annual effective dose equivalent of 10 mrem, and the limit for all release pathways in EPA's fuel-cycle standards is an annual dose equivalent to the whole body of 25 mrem. The effective dose equivalent and dose equivalent to the whole body are assumed to be the same for tritium.

The NRC's 10 CFR Part 20 also includes requirements for protection of workers within the Station boundary in the form of limits on annual effective dose equivalent and limits on concentrations of radionuclides in air and water. In addition, the EPA's drinking water standards in 40 CFR Part 141, which specify concentration limits for individual radionuclides in drinking water, are applied as groundwater protection requirements by the State of New Jersey. The drinking water standard for tritium is a concentration limit of 20,000 pCi/L. A comprehensive assessment of potential impacts of releases on humans should include comparisons of measured or calculated concentrations or doses with relevant regulatory requirements.

10.3.4 Approach to Calculation of Doses to Biota and Comparisons with Applicable Guidance

Measured or calculated concentrations of tritium in environmental media, especially surface water, also are used to estimate doses to aquatic and terrestrial biota. Because tritium in the environment behaves the same as water, doses to biota are calculated on the basis of an assumption that the activity per unit mass of water in tissues of organisms is the same as the activity per unit mass of water in the environmental medium to which an organism is exposed. Bounding estimates of dose to biota can be based on the highest measured or projected concentrations in water.

The NRC and EPA have not established standards to limit radiation exposures of biota. However, guidance on dose limits for biota, which are intended to ensure adequate protection of populations of the most sensitive species, has been developed by expert groups and adopted by the U.S. Department of Energy; this guidance is summarized in **Appendix I**. The consensus dose limits for biota, which are 0.1 or 1 rad/day depending on the type of organism, are much higher than applicable dose limits for individual workers or members of the public.

10.3.5 Approach to Calculation of Health Risks to Humans

Once doses to humans are estimated, the associated risks to human health, specifically the risks of cancer incidence associated with an exposure, can be estimated on the basis of an assumption about the cancer risk per unit dose. Estimates of cancer risk assume that any additional dose entails some risk and that risk is proportional to the dose from exposure to the source of concern. For purposes of assessing cancer risks in general terms, exposure over a lifetime often is assumed, and the assumed risk per unit dose is an average value over an individual's normal life span of about 70 years. An example calculation of the lifetime risk of cancer incidence from consumption of tritium in drinking water is given in **Appendix I.**

Estimates of health risks from exposure to tritium, or any other environmental contaminant, can be used to provide a perspective on the significance of estimated exposures. By comparing calculated cancer risks with other risks experienced in everyday life, including unavoidable risks from exposure to natural background radiation, a frame of reference that would allow affected individuals to judge the significance of potential exposures is provided.

For example, a useful frame of reference for evaluating the significance of doses due to releases of tritium would be to compare estimated doses with doses from exposure to naturally occurring tritium produced in the atmosphere and tritium produced by atmospheric testing of nuclear weapons. Doses from these sources are unavoidable and are experienced by all members of the public. The National Council on Radiation Protection and Measurements (NCRP) has estimated that the annual dose from exposure to naturally occurring tritium produced in the atmosphere is about 0.001 millirem (mrem), and the annual dose from exposure to tritium produced by atmospheric testing of nuclear weapons currently is about 0.003 mrem (NCRP 1979). In comparison, the total annual dose from all sources of natural background radiation is about 100 mrem, excluding indoor radon, and about 300 mrem if indoor radon is included.

Estimates of health risks as described above are not relevant for biota, because cancer is not a biological effect of concern and current guidance on dose limits is based on an assumption that all species will be adequately protected if doses are maintained below specified limits, even though individual members of species may be harmed. Potential impacts on species can be indicated in a general way by comparing estimated doses with dose limits in the guidance. The lower the estimated doses relative to the limits, the greater the margin of safety in protecting species of aquatic and terrestrial biota.

10.4 Assessment of Potential Off-Site Exposures of Humans and Biota

There is no evidence to date to indicate that a significant quantity of tritium in groundwater has migrated or is presently migrating beyond the boundary of the Salem site. Elevated levels of tritium have been found only in the water table aquifer on the site, and there is no evidence that tritium in shallow groundwater has migrated directly to the Delaware River or to an underlying aquifer that provides a source of drinking water for the local population. Thus, on the basis of present knowledge, an exposure pathway to humans beyond the site boundary or to biota has not been completed, and there is no basis for performing an assessment of potential off-site exposures of humans and biota.

11 Conclusions and Recommendations

The following sections provide conclusions and recommendations based on the results of remedial investigation activities conducted to date.

11.1 Conclusions

The following detailed conclusions are presented that support the evidence that the source of tritium detected in groundwater was the Spent Fuel Pool, the tritium released to the environment has been stopped, and that tritium has not migrated to the property boundary above any regulatory limit:

1. There was a release of water from the Spent Fuel Pool system resulting from blockage of the telltale drains by mineral precipitates. The telltale drains are a leak monitoring, collection, and drainage mechanism specifically designed to collect leakage that may accumulate behind the stainless steel liner of the Spent Fuel Pool and Refueling Canal. The blockage of the telltale drains resulted in the accumulation of water from the Spent Fuel Pool system (between the liner and the concrete wall) that created hydrostatic head and facilitated migration to the Styrofoam-filled seismic gap located between the Salem Unit 1 Fuel Handling Building and Auxiliary Building. The mineral precipitates have been physically removed to ensure the proper operation of the telltale drains. The process of monitoring the telltale drains is routinely performed to ensure that blockage does not reoccur. Permanent seismic gap drains are being installed to facilitate control of the accumulation of water in the seismic gap, and to create an ingradient to the gap;

2. The release of water from the Spent Fuel Pool system was investigated through the sampling of monitoring wells installed in the area of Salem Unit 1. The groundwater analytical data collected from the monitoring well network were used to delineate an area of groundwater in the shallow, water-bearing unit that contains elevated concentrations of tritium. Gamma-emitting isotopes were also monitored in the groundwater samples collected from the monitoring wells because the suspected source of the tritium was the Spent Fuel Pool. No plant related gamma-emitting isotopes have been detected in groundwater samples collected from the monitoring wells;

3. The area of groundwater containing elevated tritium extends from the southern end of the Styrofoam seismic gap located between the Salem Auxiliary Building and the Salem Unit 1 Reactor Containment Building in a southerly direction toward the circulation water discharge pipes. Groundwater with tritium at concentrations

exceeding any regulatory limit has not migrated to the property boundary of the Station;

4. Elevated levels of tritium have only been detected in groundwater samples collected from the shallow, water-bearing unit. There is no evidence that suggests that water from the Spent Fuel Pool has migrated to an underlying aquifer as confirmed by groundwater samples collected from monitoring wells screened in the Vincentown Formation;

5. A completed exposure pathway to humans from tritium in shallow groundwater has not been established, nor is there any evidence that significant exposures of biota have occurred.

11.2 Recommendations

Based on the conclusions of the remedial investigation, the following recommendations are presented:

1. Continued groundwater monitoring should be conducted on a periodic basis. This groundwater monitoring should include the collection of groundwater samples from monitoring wells screened in the shallow, water-bearing unit on a monthly or quarterly basis, to be determined based on quantitative parameters. During these sampling events, depth to water-level measurements should be collected from site monitoring wells. Groundwater samples should also be collected from monitoring wells screened in the Vincentown Formation on a semi-annual basis.

2. A pilot test should be conducted to evaluate the feasibility of groundwater extraction, to provide engineering data to support the extraction system design, and to initially contain the further migration of tritium in groundwater near Salem Unit 1.

3. A Remedial Action Workplan (RAW) should be prepared in accordance with the Technical Requirements for Site Remediation (N.J.A.C. 7:26E). The RAW will be submitted within 90 days of approval of the Remedial Investigation Report.

12 References

ARCADIS, June 2003; Remedial Investigation Work Plan, PSEG Nuclear LLC, Salem Generating Station, Hancock's Bridge, New Jersey.

ARCADIS, January 2004; Initial Groundwater Investigation Report and Remedial Investigation Work Plan Addendum, PSEG Nuclear LLC, Salem Generating Station, Hancock's Bridge, New Jersey.

Dames & Moore, August 28, 1968, Report, Foundation Studies, Proposed Salem Generating Station.

Dames & Moore, December16, 1968, Report, Groundwater Supply Investigation, Salem Generating Station.

Dames & Moore, April 9, 1969, Supplemental Report, Control of Excavation, Salem Generating Station.

Dames & Moore, June 3, 1970, Report, Supplementary Studies, Proposed Salem Generating Station.

Dames & Moore, June 20, 1972, Report, Consultation, Proposed Heavy Equipment Haul Road, Salem Generating Station.

Dames & Moore, February 7, 1974, Design, High Water Levels, Proposed Hope Creek Generating Station.

Dames & Moore, May 23, 1974, Report, Foundation Studies, Proposed Hope Creek Generating Station.

Dames & Moore, July 6,1976, Report Auxiliary Boring Program Along Service Water Supply Lines, Hope Creek Generating Station.

Dames & Moore, June 1977, Evaluation of Shoreline Stability, Hope Creek Generating Station.

Dames & Moore, February 27, 1981, Final Report, Seismic Ground Motion and Site Stability Evaluation at the Controlled Facilities Building, Salem Generating Station.

Dames & Moore, 1988, Final Report, Study of Long-Term Groundwater Withdrawals and Water-Supply Alternatives, Salem and Hope Creek Generating Stations.

Dames & Moore, December 23, 1992; Report, Geotechnical Investigation and Evaluation, Proposed Oil-Water Separator Basin, Salem Generating Stations.

NJGS, 1995, Geologic Survey Report GSR 38, Ground-Water Flow Conditions in the Potomac-Raritan-Magothy aquifer System, Camden Area, New Jersey.

United States Department of Agriculture (USDA) Natural Resources Conservation Service National Water & Climate Center. 1988. *Field Office Guide to Climatic Data*, last revised 18 November 1998.

USGS, 1979, Geological Survey Professional Paper 1067-D, Upper Cenozoic Sediments of the Lower Delaware Valley and the Northern Delmarva Peninsula, New Jersey, Pennsylvania, Delaware, and Maryland.

USGS, 1999, Water-Resources investigations report 98-4136, Hydrogeology of, Water Withdrawal from, and Water levels and Chloride Concentrations in the Major Coastal plain Aquifers of Gloucester and Salem Counties, New Jersey. West Trenton New Jersey.

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Table 01. Physical and Chemical Properties of Constituents of Concern, PSEG Nuclear, LLC, Salem Generating Station, Hancock's Bridge, New Jersey.

			K_d (mL/g)			Retardation Factor[1]				
Constituent of Concern	**Molecular Weight (g/mol)**	**Specific Gravity[2]**	**Minumum**	**Maximum**	**Recommended[3]**	**Minimum**	**Maximum**	**Recommended[3]**	**Half-Life**	**Half-Life Units**
Antimony-125	124.905	6.68	0	10,000	3,981	1	68,901	27,431	2.758	years
Barium-133	132.906	3.62	NR	NR	--	--	--	--	10.53	years
Barium-140/Lanthanum-140	139.911/139.909	3.62	NR	NR	--	--	--	--	12.75/1.678	days
Berium-7	7.0169		NR	NR	--	--	--	--	53.28	days
Boron	10.811	2.34	0	3,990	0	1.00	27,492	1	NR	
Cerium-141	140.908	6.77	10	10,000	1,000	69.9	68,901	6,891	32.5	days
Cerium-144	143.914	6.77	10	10,000	1,000	69.9	68,901	6,891	284.6	days
Cesium-133	132.906	1.93	1	100,000	501	7.89	689,001	3,454	NR	
Cesium-134	133.907	1.93	1	100,000	501	7.89	689,001	3,454	2.065	years
Cesium-137	136.907	1.93	1	100,000	501	7.89	689,001	3,454	30.2	years
Chromium-51	50.945	7.15	1	1,000	40	7.89	6,891	275	27.7	days
Cobalt-58	57.936	8.86	0.1	1,000	10	1.689	6,891	70	70.88	days
Cobalt-60	59.934	8.86	0.1	1,000	10	1.689	6,891	70	5.271	years
Iodine-129	128.904	4.93	0.001	1	0.20	1.00689	9	2	1.70E+07	years
Iodine-131	130.906	4.93	0.001	2	0.20	1.00689	15	2	8.04	days
Iron-59	58.935	7.87	NR	NR	--	--	--	--	44.51	days
Manganese-54	53.94	7.3	NR	NR	--	--	--	--	312.1	days
Molybdenum-99	98.908	10.2	0	100	--	1	690	--	2.748	days
Potassium-40	39.964	0.89	NR	NR	--	--	--	--	1.26E+09	years
Radium-Natural (Ra-226)	226.0254	5	5	1,000,000	100	35.45	6,890,001	690	1599	years
Ruthenium-103	102.906	12.1	100	1,000	158	690	6,891	1,093	39.27	days
Ruthenium-106	105.907	12.1	100	1,000	158	690	6,891	1,093	1.02	years
Silver-110M	109.906	10.5	10	1,000	100	69.9	6,891	690	249.8	days
Sodium-22	21.994	0.97	NR	NR	--	--	--	--	2.605	years
Technetium-99	98.906	11	0	100	0.001	1	690	1	2.13E+05	years
Tellurium-129M	128.906	6.24	NR	NR	--	--	--	--	33.6	days
Tellurium-132	131.909	6.24	NR	NR	--	--	--	--	3.26	days
Thorium-232	232.038	11.7	10	100,000	100	69.9	689,001	690	1.40E+10	years
Thorium-234	234.044	11.7	10	100,000	100	69.9	689,001	690	24.1	days
Tritium	3.016	0.2693	0.001	0	0.001	1.00689	1	1	12.33	years
Uranium-235	235.044	19.1	0.1	1,000,000	40	1.689	6,890,001	275	7.04E+08	years
Zinc-65	64.929	7.14	0.1	10,000	16	1.689	68,901	110	243.8	days
Zirconium-95/Niobium-95	94.908	6.52	260	500	--	1792.4	3,446	--	64.02	days

NOTES:

[1] Assumes an effective porosity of 0.25 and a bulk density of 1.7225

NR Not Reported

[2] Value for the stable isotope

[3] Based on Looney et al., 1988

Boron K_d values The table presents the entire range reported in the literature, mostly derived from soil systems. It is likely that K_d is negligible in low clay, sandy aquifer sediments.

References:

Looney, B.B., Grant, M.W., King, C.M., 1987, Estimation of Geochemical Parameters for Assessing Subsurface Transport at the Svannah River Plant: DPST-85-904.

Spitz K. and Moreno, J., 1996, A Practical Guide to Groundwater and Solute Transport Modeling: John Wiley and Sons, New York.

Montgomery J.H., 2000, Groundwater Chemicals Desk Reference: Lewis Publishers, Boca Raton.

Lide, D.R., 2003, CRC Handbook of Chemistry and Physics, 83rd Edition: CRC Press, Boca Raton.

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Table 02. Groundwater Analytical Results, Phase I Investigation, October through November 2002, PSEG Salem Generating Station, Hancock's Bridge, New Jersey.

Constituent of Concern	Sample Identification[1] and Collection Date							
	A2 10/02/02	B 10/03/02	C26 10/04/02	C33 10/04/02	A1 10/04/02	E 10/05/02	A2 11/22/02	A2 11/22/02
Major Cations and Anions (mg/L)								
Boron	NA	NA	NA	NA	NA	**2,600**	NA	NA
Gamma Emmitting Isotopes (pCi/L)								
Potassium-40	**1,490**	**3,780**	**5,960**	**6,450**	NA	NA	**1,760**	**1,970**
Cesium-134	NA	NA	NA	NA	NA	**118,000**	NA	NA
Cesium-137	NA	NA	NA	NA	NA	**320,000**	NA	NA

Notes:

mg/L	Milligrams per liter
pCi/L	Picocuries per liter
NA	Constituent not analyzed
	Bold values exceed the laboratory detection limit.
1	Corresponds with sample locations shown on Figure 10.

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Table 03. Groundwater Analytical Results, Phase II Investigation, December 2002, PSEG Salem Generating Station, Hancock's Bridge, New Jersey.

Sample Identification[1]	Sample Date	Sodium (mg/L)	Chlorine (mg/L)	Boron (mg/L)	Tritium (pCi/L)	Gamma Emmitting Isotopes (pCi/L)												
						Potassium-40	Chromium-51	Manganese-54	Cobalt-58	Cobalt-60	Antimony-125	Iodine-131	Cesium-134	Cesium-137	Radium-Nat	Thorium-234	Uranium-235
Production Wells and Observation Wells																	
HC-1	12/12/2002	NA	NA	NA	<160	**53.3**	<6.64	<0.881	<0.892	<1.25	<2.87	<0.863	<0.614	<1.18	**17.6**	NA	NA
HC-2	12/12/2002	NA	NA	NA	<166	**75.0**	<6.80	<0.822	<1.11	<0.985	<1.99	<0.992	<0.895	<1.86	**51.9**	NA	NA
PW-2	12/12/2002	NA	NA	NA	<167	**66.3**	<6.81	<0.649	<0.747	<1.02	<2.33	<0.936	<0.841	<1.11	**58.0**	NA	NA
PW-5	12/12/2002	NA	NA	NA	<162	**43.7**	<4.01	<1.20	<0.793	<0.681	<1.37	<0.457	<0.803	<1.31	**17.0**	NA	NA
PW-6	12/12/2002	NA	NA	NA	<156	**42.4**	<6.45	<0.902	<0.630	<0.813	<1.45	<0.601	<0.541	<0.850	**18.0**	NA	NA
Obs G	12/13/2002	NA	NA	NA	<169	**64.2**	<6.62	<1.28	<0.988	<1.26	<3.75	<0.842	<1.19	<1.66	**221**	**42.10**	**3.90**
Obs J	12/13/2002	NA	NA	NA	<161	**31.0**	<5.72	<0.424	<0.562	<0.788	<1.95	<0.685	<0.832	<0.780	**19.2**	**53.10**	**1.79**
Direct-Push Discrete Water Samples																	
DP-1	12/19/02 14:37	**14.0**	**5.5**	**1,705**	**137,000,000**	NA	NA	NA	NA	**6,779**	**24,870**	NA	**75,790**	**254,100**	NA	NA	NA
DP-1	12/20/02 9:30	**10.4**	**0.33**	**1,968**	**120,000,000**	NA	NA	**1,057**	**1,025**	**2,107**	**1,776**	**2,591**	**40,570**	**132,600**	NA	NA	NA
DP-2	12/20/02 13:00	**98.0**	**0.39**	**684**	**69,800,000**	NA	NA	**234**	NA	NA	NA	**794**	**23,760**	**72,710**	NA	NA	NA
DP-2	12/20/02 13:25	**40.6**	**0.43**	**1,293**	**121,000,000**	NA	NA	**201**	NA	**316**	NA	**1,595**	**19,650**	**64,930**	NA	NA	NA
DP-2	12/20/02 14:00	**22.6**	**0.50**	**1,725**	**182,000,000**	NA	NA	**697**	NA	**784**	NA	**2,134**	**32,290**	**102,800**	NA	NA	NA
DP-2	12/20/02 14:40	**23.3**	**0.56**	**1,771**	**179,000,000**	NA	NA	**972**	**638**	**3,877**	**3,635**	**2,362**	**40,240**	**133,900**	NA	NA	NA

Notes:

mg/L Milligrams per liter
pCi/L Picocuries per liter
14.0 *Result was detected above laboratory method detection limit.*
<6.64 Laboratory method detection limit.
ND Analyte was not detected; laboratory detection limit is not known.
NA Constituent not analyzed.
[1] Corresponds with sample locations shown on Figure 10.

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Table 04. Well Construction Details, PSEG Nuclear, LLC, Salem Generating Station, Hancock's Bridge, New Jersey.

Well ID	Installation Date	Purpose	Construction Details	Diameter (inches)	Total Depth (feet bgs)	Monitoring Interval (feet bgs)	Monitored Hydrogeologic Unit	MP Elevation (feet RPD)	MP Elevation (feet amsl)	Northing (NAD 83)	Easting (NAD 83)
Well K	Feb-03	Monitoring	Sch-40 PVC	2	80.0	70.0 - 80.0	Vincentown[1]	102.00	12.08	231,435	199,697
Well L	Jan-03	Monitoring	Sch-40 PVC	2	80.0	70.0 - 80.0	Vincentown[1]	101.46	11.54	230,933	199,263
Well M	May-03	Monitoring	Sch-40 PVC	1	20.0	10.0 - 20.0	Cofferdam[2]	102.17	12.25	230,843	199,546
Well N	Jan-03	Monitoring	Sch-40 PVC	2	20.0	10.0 - 20.0	Cofferdam[2]	101.65	11.73	230,777	199,661
Well O	Jan-03	Monitoring	Sch-40 PVC	2	20.0	10.0 - 20.0	Cofferdam[2]	101.33	11.41	230,804	199,839
Well P	Mar-03	Monitoring	Sch-40 PVC	2	80.0	70.0 - 80.0	Vincentown[1]	101.13	11.21	230,336	200,000
Well Q	Mar-03	Monitoring	Sch-40 PVC	2	80.0	70.0 - 80.0	Vincentown[1]	106.59	16.67	230,645	201,196
Well R	Jun-03	Monitoring	Sch-40 PVC	1	19.0	9.0 - 19.0	Cofferdam[2]	102.35	12.43	230,906	199,640
Well S[4]	May-03	Monitoring	Sch-40 PVC	2	34.7	24.7 - 34.7	Shallow[3]	99.04	9.12	230,711	199,613
Well T	Jun-03	Monitoring	Sch-40 PVC	2	31.2	21.2 - 31.2	Shallow[3]	104.13	14.21	231,575	199,575
Well U[4]	May-03	Monitoring	Sch-40 PVC	2	32.2	27.2 - 32.2	Shallow[3]	98.57	8.65	231,370	199,618
Well V[4]	Jun-03	Monitoring	Sch-40 PVC	2	79.5	69.5 - 79.5	Vincentown[1]	98.74	8.82	231,355	199,548
Well W[4]	Jun-03	Monitoring	Sch-40 PVC	2	35.0	25.0 - 35.0	Shallow[3]	98.69	8.77	230,777	199,450
Well Y	Sep-03	Monitoring	Sch-40 PVC	2	37.0	27.0 - 35.0	Shallow[3]	101.81	11.89	230,771	199,343
Well Z	Sep-03	Monitoring	Sch-40 PVC	2	37.5	27.5 - 37.5	Shallow[3]	101.86	11.94	230,681	199,399
Well AA[4]	Sep-03	Monitoring	Sch-40 PVC	2	36.0	26.0 - 36.0	Shallow[3]	99.07	9.15	230,603	199,541
Well AB[4]	Oct-03	Monitoring	Sch-40 PVC	2	42.0	32.0- 42.0	Shallow[3]	98.93	9.01	230,623	199,677
Well AC[4]	Sep-03	Monitoring	Sch-40 PVC	2	24.0	14.0 - 24.0	Cofferdam[2]	98.77	8.85	230,724	199,725
Well AD[4]	Oct-03	Monitoring	Sch-40 PVC	6	43.0	33.0 - 43.0	Shallow[3]	98.99	9.07	230,684	199,607
Well AE	Oct-03	Monitoring	Sch-40 PVC	2	37.5	27.5 - 37.5	Cofferdam[2]	101.54	11.62	230,829	199,845
Well AF	Oct-03	Monitoring	Sch-40 PVC	2	45.0	35.0 - 45.0	Shallow[3]	101.61	11.69	230,491	199,702
Well AG-Shallow	Feb-04	Monitoring	Sch-40 PVC	1	24.2	14.2 - 24.2	Shallow[3]	99.29	9.37	230,496	199,508
Well AG-Deep	Feb-04	Monitoring	Sch-40 PVC	1	40.0	30.0 - 40.0	Shallow[3]	99.20	9.28	230,496	199,508
Well AH-Shallow	Feb-04	Monitoring	Sch-40 PVC	1	24.5	14.5 - 24.5	Shallow[3]	102.58	12.66	230,450	199,596
Well AH-Deep	Feb-04	Monitoring	Sch-40 PVC	1	40.0	30.0 - 40.0	Shallow[3]	102.70	12.78	230,450	199,596
Well AI	Jan-04	Monitoring	Sch-40 PVC	4	22.0	12.0 - 22.0	Cofferdam[2]	98.79	8.87	230,798	199,521
Well AJ	Jan-04	Monitoring	Sch-40 PVC	4	35.3	15.3 - 35.3	Shallow[3]	98.85	8.93	230,670	199,665
Well AL	Jan-04	Monitoring	Sch-40 PVC	2	25.3	15.3 - 25.3	Shallow[3]	99.13	9.21	230,594	199,806
Well AM	Jan-04	Monitoring	Sch-40 PVC	4	20.9	10.9 - 20.9	Cofferdam[2]	98.55	8.63	230,762	199,680

Notes:

MP Measuring Point

bgs Below ground surface

RPD Relative to plant datum

amsl Relative to mean sea level (NAVD 1988).

1 Monitoring well is screened in the Vincentown Formation.

2 Monitoring well is screened in the shallow, water-bearing unit at a location within the limits of the cofferdam.

3 Monitoring well is screened in the shallow, water-bearing unit at a location outside the limits of the cofferdam.

4 The surface completions of Monitoring Wells S, U, V, W, AA, AB, AC, and AD were converted from above-grade to flush-grade in February 2004.

Table 05. Supplemental Groundwater Investigation Details, PSEG Nuclear, LLC, Salem Generating Station, Hancock's Bridge, New Jersey.

Boring Identification	Comments/Details	Groundwater Sample Interval (ft bgs)				Groundwater Sample Analysis			
		11 to 15[1]	21 to 25[1]	15 to 25[2]	31 to 35[1]	Tritium - Salem[3]	Tritium - Maplewood[4]	Boron	Gamma-Emitting Isotopes[5]
1		X	X	--	X	X	X	X	X
2		--	--	X	X	X	X	X	X
3		--	--	X	X	X	X	X	X
4		--	--	X	X	X	X	X	X
5	Unable to advance boring due to obstruction.	--	--	--	--	--	--	--	--
6	Unable to advance boring due to obstruction.	--	--	--	--	--	--	--	--
7		X	X	--	X	X	X	X	X
8		--	--	X	X	X	--	--	--
9	Equipment refusal encountered at 22 ft bgs.	--	X(18-22)	--	--	X	--	--	--
10	Equipment refusal encountered at 21.5 ft bgs.	--	X(17.5-21.5)	--	--	X	--	--	--
11	Unable to advance boring due to obstruction.	--	--	--	--	--	--	--	--
12		X(8-9)	--	X	--	X	X	--	X

Notes:

ft bgs - Feet below ground surface.

1 Groundwater samples collected from the 11 to 15, 21 to 25 and 31 to 35 foot below ground surface intervals were collected using the Geoprobe® four-foot SP-15 Screened Point Groundwater Sampler.

2 Groundwater samples collected from the interval of 15 to 25 foot below ground surface were collected from a temporary one-inch diameter PVC well. The temporary wells were installed to facilitate the collection of groundwater samples in areas/intervals that did not yield sufficient groundwater.

3 Refers to the PSEG Nuclear, LLC Station Chemistry. Initial analysis of groundwater samples was conducted at the on-site laboratory for screening purposes. If tritium concentrations indicated by the groundwater sample were below the detection limits of Station chemistry, the sample was submitted to Maplewood Testing Services for analysis.

4 Maplewood Testing Services.

5 The list of gamma-emitting isotopes included: Potassium-40; Actinium-228; Lead-221; Bismuth-212; Thallium-208; Thorium-234; Lead-214; Bismuth-214; Cesium-137; and, Uranium-235.

-- Indicates that either a sample was attempted and was unsuccessful, the collection of water from the interval was not attempted, and/or the analysis was not performed.

X - Indicates that a groundwater sample was collected from the listed sample interval, unless otherwise indcated (e.g., "18-22), and was subsequently analyzed for the indicated parameters.

Table 05. Supplemental Groundwater Investigation Details, PSEG Nuclear, LLC, Salem Generating Station, Hancock's Bridge, New Jersey.

Boring Identification	Comments/Details	Groundwater Sample Interval (ft bgs)				Groundwater Sample Analysis			
		11 to 15[1]	21 to 25[1]	15 to 25[2]	31 to 35[1]	Tritium - Salem[3]	Tritium - Maplewood[4]	Boron	Gamma-Emitting Isotopes[5]
13		--	--	X	--	X	X	--	--
14		--	--	X	X	X	X	--	--
15		--	--	X	X	X	X	--	X
16	Unable to advance boring due to obstruction.	--	--	--	--	--	--	--	--
17	Unable to advance boring due to obstruction.	--	--	--	--	--	--	--	--
18		--	--	X	X	X	--	--	--
19		X	--	X(14-18)	--	X	--	--	--
20		--	--	X	X	X	--	--	--
21	Unable to advance boring due to obstruction.	--	--	--	--	--	--	--	--
22	Equipment refusal encountered at 33 ft bgs.	X	X	--	X(29-33)	X	X	--	X
23		--	--	X	X	X	X	--	X
24		--	--	--	X	X	X	--	X

Notes:

ft bgs - Feet below ground surface.

1 Groundwater samples collected from the 11 to 15, 21 to 25 and 31 to 35 foot below ground surface intervals were collected using the Geoprobe® four-foot SP-15 Screened Point Groundwater Sampler.

2 Groundwater samples collected from the interval of 15 to 25 foot below ground surface were collected from a temporary one-inch diameter PVC well. The temporary wells were installed to facilitate the collection of groundwater samples in areas/intervals that did not yield sufficient groundwater.

3 Refers to the PSEG Nuclear, LLC Station Chemistry. Initial analysis of groundwater samples was conducted at the on-site laboratory for screening purposes. If tritium concentrations indicated by the groundwater sample were below the detection limits of Station chemistry, the sample was submitted to Maplewood Testing Services for analysis.

4 Maplewood Testing Services.

5 The list of gamma-emitting isotopes included: Potassium-40; Actinium-228; Lead-221; Bismuth-212; Thallium-208; Thorium-234; Lead-214; Bismuth-214; Cesium-137; and, Uranium-235.

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Table 05. Supplemental Groundwater Investigation Details, PSEG Nuclear, LLC, Salem Generating Station, Hancock's Bridge, New Jersey.

Boring Identification	Comments/Details	Groundwater Sample Interval (ft bgs)				Groundwater Sample Analysis			
		11 to 15[1]	21 to 25[1]	15 to 25[2]	31 to 35[1]	Tritium - Salem[3]	Tritium - Maplewood[4]	Boron	Gamma-Emitting Isotopes[5]
25	Equipment refusal encountered at 25 ft bgs.	--	--	X	--	X	X	--	X
26	Equipment refusal encountered at 32 ft bgs.	--	--	X	X(28-32)	X	X	--	X
27		X	--	--	X	X	X	--	X
28		X	X	--	X	X	X	--	X
29	Unable to advance boring due to obstruction.	--	--	--	--	--	--	--	--
30		--	--	X	X	X	--	--	--
31		--	--	X	X(34-38)	X	--	--	--
32		--	--	X	X(34-38)	X	--	--	--
33	Equipment refusal encountered at 19 ft bgs.	--	X(9-19)	--	--	X	--	--	--
34	Equipment refusal encountered at 22 ft bgs.	--	X(12-22)	--	--	X	--	--	--
35	Equipment refusal encountered at 24 ft bgs.	--	X(14-24)	--	--	X	--	--	--
36	Equipment refusal encountered at 16 ft bgs.	X	--	--	--	X	--	--	--
37	Boring was not advanced deeper than 25 ft bgs.	--	--	X	--	X	--	--	--

Notes:

ft bgs - Feet below ground surface.

[1] Groundwater samples collected from the 11 to 15, 21 to 25 and 31 to 35 foot below ground surface intervals were collected using the Geoprobe® four-foot SP-15 Screened Point Groundwater Sampler.

[2] Groundwater samples collected from the interval of 15 to 25 foot below ground surface were collected from a temporary one-inch diameter PVC well. The temporary wells were installed to facilitate the collection of groundwater samples in areas/intervals that did not yield sufficient groundwater.

[3] Refers to the PSEG Nuclear, LLC Station Chemistry. Initial analysis of groundwater samples was conducted at the on-site laboratory for screening purposes. If tritium concentrations indicated by the groundwater sample were below the detection limits of Station chemistry, the sample was submitted to Maplewood Testing Services for analysis.

[4] Maplewood Testing Services.

[5] The list of gamma-emitting isotopes included: Potassium-40; Actinium-228; Lead-221; Bismuth-212; Thallium-208; Thorium-234; Lead-214; Bismuth-214; Cesium-137; and, Uranium-235.

-- Indicates that either a sample was attempted and was unsuccessful, the collection of water from the interval was not attempted, and/or the analysis was not performed.

X - Indicates that a groundwater sample was collected from the listed sample interval, unless otherwise indcated (e.g., "18-22), and was subsequently analyzed for the indicated parameters.

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Table 06. Supplemental Groundwater Investigation Results, PSEG Nuclear, LLC, Salem Generating Station, Artificial Island, Hancock's Bridge, New Jersey.

Boring Identification	Sample Interval (ft bgs)	Tritium (pCi/L)		Boron (ug/L)	Gamma-Emitting Isotopes (pCi/L) Potassium - 40	Bismuth - 212 (Thorium - 232)	Thorium - 234 (Uranium - 238)	Uranium - 235
		Salem[1]	Maplewood[2]	Maplewood[2]	Maplewood[2]	Maplewood[2]	Maplewood[2]	Maplewood[2]
1	11 - 15	<6,800	<138	--	--	--	--	--
	21 - 25	<5,960	--	--	--	--	--	--
	31 - 35	<5,740	<139	812	81.5	<4.45	84.7	5.59
2	15 - 25	<5,190	<145	578	<23.5	<6.70	<103	<4.47
	31 - 35	<5,380	206	635	<26.8	<4.35	<69.1	<4.53
3	15 - 25	<4,740	<140	641	97.9	<13.8	<11.0	4.76
	31 - 35	<5,420	986	393	<80.2	<6.33	<50.0	<3.78
4	15 - 25	<5,790	<142	626	65.4	<13.1	175	4.75
	31 - 35	<5,520	271	457	<10.2	<4.99	<50.2	<1.78
7	11 - 15	<5,020	<142	266	51.3	<5.45	<128	<5.05
	21 - 25	<5,020	222	318	75.5	<7.47	<46.0	<3.88
	31 - 35	<5,090	2,545	690	71.9	<4.33	<38.5	<2.63
8	15 - 25	<6,670	1,175	206	57.0	<4.80	<7.91	<3.87
	31 - 35	<14,600	1,731	510	<42.6	<4.78	199	4.53
9	18 - 22	80,800	--	--	--	--	--	--
10	17.5 - 21.5	21,300	--	--	--	--	--	--
12	8 - 9	<4,540	1,941	365	<14.7	<3.68	169	6.00
	15 - 25	<4,380	1,814	291	82.7	<8.57	187	3.90
13	15 - 25	<5,410	579	457	46.6	<10.7	165	6.47
14	15 - 25	5,860	8,674	--	<15.0	<3.68	198	5.27
	31 - 35	<5,590	10,190	--	--	--	--	--
15	15 - 25	<5,210	726	407	96.5	18.5	<119	5.83
	31 - 35	<5,170	756	411	<56.0	<3.94	<144	<4.61
18	15 - 25	<15,500	499	143	50.2	15.2	209	6.17
	31 - 35	<14,600	396	675	99.0	<7.48	<112	<5.31
19	11 - 15	114,000	--	--	--	--	--	--
	14 - 18	591,000	--	--	--	--	--	--
20	15 - 25	461,000	--	--	--	--	--	--
	31 - 35	172,000	--	--	--	--	--	--
22	11 - 15	<4,750	920	408	<34.9	<4.13	<105	<2.98
	21 - 25	<4,700	1,433	268	<22.7	<4.10	150	<1.27
	29 - 33	<6,020	8,449	301	<35.3	<13.5	180	6.59
23	15 - 25	<3,920	567	--	<56.0	<5.09	<40.3	<4.23
	31 - 35	<7,210	474	344	--	--	--	--

Notes:

ft bgs — Feet below ground surface.
pCi/L — Picocuries per liter.
ug/L — micrograms per liter.
< — Less than the laboratory detection limit.
-- — Constituent not analyzed.
1 — Refers to PSEG Nuclear, LLC Station Chemistry. If tritium concentrations indicated by a groundwater sample were below the detection limits of Station chemistry, the sample was submitted to Maplewood Testing Services for analysis. Initial analysis of groundwater samples was conducted at the Salem on-site laboratory for screening purposes.
2 — Maplewood Testing Services.

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Table 06. Supplemental Groundwater Investigation Results, PSEG Nuclear, LLC, Salem Generating Station, Artificial Island, Hancock's Bridge, New Jersey.

Boring Identification	Sample Interval (ft bgs)	Tritium (pCi/L)		Boron (ug/L)	Gamma-Emitting Isotopes (pCi/L) Potassium - 40	Bismuth - 212 (Thorium - 232)	Thorium - 234 (Uranium - 238)	Uranium - 235
		Salem [1]	Maplewood [2]	Maplewood [2]	Maplewood [2]	Maplewood [2]	Maplewood [2]	Maplewood [2]
24	31 - 35	<4,790	361	188	43.1	<9.04	<130	<3.87
25	15 - 25	<4,610	1,500	409	<48.4	<5.82	<120	<4.52
26	15 - 25	<4,500	4,127	582	97.6	<9.56	<62.6	<5.52
	28 - 32	6,760	--	--	--	--	--	--
27	11 - 15	620,000	--	--	--	--	--	--
	31 - 35	<4,930	1,028	710	67.5	<6.63	<61.7	<3.21
28	11 - 15	45,000	--	--	--	--	--	--
	21 - 25	1,980,000	--	--	--	--	--	--
	31 - 35	<5,140	1,794	660	95.4	<6.55	<109	<4.55
30	15 - 25	<14,900	406	339	70.2	<5.83	152	<1.46
	31 - 35	<15,500	<142	228	<14.4	<4.38	143	3.71
31	15 - 25	<15,500	<140	--	--	--	--	--
	34 - 38	<15,500	<141	--	47.9	<4.61	<63.9	<3.35
32	15 - 25	<15,500	<139	793	197	<13.0	457	<10.0
	34 - 38	<15,700	168	--	<11.6	<6.11	<72.2	<4.38
33	9 - 19	1,080,000	--	--	--	--	--	--
34	12 - 22	698,000	--	--	--	--	--	--
35	14 - 24	1,250,000	--	--	--	--	--	--
36	11 - 16	<15,300	11,404	--	--	--	--	--
37	15 - 25	<15,200	4,550	181	<42.8	16.8	<91.2	<4.15

Notes:

ft bgs — Feet below ground surface.
pCi/L — Picocuries per liter.
ug/L — micrograms per liter.
< — Less than the laboratory detection limit.
-- — Constituent not analyzed.
1 — Refers to PSEG Nuclear, LLC Station Chemistry. If tritium concentrations indicated by a groundwater sample were below the detection limits of Station chemistry, the sample was submitted to Maplewood Testing Services for analysis. Initial analysis of groundwater samples was conducted at the Salem on-site laboratory for screening purposes.
2 — Maplewood Testing Services.

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Table 07. Field Parameter Measurements, PSEG Nuclear, LLC, Salem Generating Station, Hancock's Bridge, New Jersey.

		Parameter					
Observation Well Identification	Date	pH (SU)	Specific Conductance (mS/cm)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Temperature (°C)	Oxidation-Reduction Potential (mV)
Well K	04/29/03	7.10	8.58	18.5	0.37	18.23	21
	05/05/03	6.80	7.55	12.0	0.23	14.90	-107
	05/20/03	7.13	7.68	13.2	0.22	16.93	-174
	05/28/03	7.17	7.84	15.1	0.20	15.97	-153
	06/04/03	7.04	7.92	14.4	0.14	14.91	-173
	06/10/03	7.10	7.06	14.4	0.25	17.44	-140
	06/17/03	7.18	7.02	17.8	0.10	16.00	-184
	06/24/03	7.11	8.62	1.8	0.16	17.61	-186
	06/30/03	7.30	8.28	11.1	0.14	18.52	-142
	07/16/03	7.24	8.23	6.5	0.19	18.31	-102
	07/29/03	7.19	8.47	7.0	0.13	18.09	-127
	08/12/03	6.95	8.37	1.6	0.21	19.06	-58
	08/27/03	6.91	8.17	5.6	0.41	19.75	-64
	09/09/03	6.93	8.01	5.5	0.72	18.89	-38
	09/25/03	7.13	8.3	5.8	1.67	18.51	-22
	10/06/03	6.75	8.29	20.0	2.44	17.22	-14
	11/09/03	6.84	8.19	3.1	0.30	15.75	-25
Well L	04/29/03	7.40	14.11	13.3	0.36	16.35	-75
	05/05/03	7.00	13.29	11.0	1.35	12.50	-166
	05/15/03	7.45	13.12	6.3	0.42	15.09	-183
	05/20/03	7.38	12.98	8.8	0.22	15.48	-201
	05/28/03	7.39	13.52	11.0	0.34	15.04	-160
	06/04/03	7.31	13.44	10.0	0.29	14.64	-191
	06/10/03	7.45	11.98	9.4	0.20	16.94	-150
	06/17/03	7.38	12.03	13.2	0.18	15.59	-185
	06/24/03	7.36	14.90	1.2	0.18	16.70	-199
	06/30/03	7.43	14.14	9.7	0.17	17.32	-160
	07/29/03	7.40	14.29	11.0	0.14	16.99	-140
	08/27/03	7.08	14.07	9.4	0.13	17.67	-35
	09/25/03	7.37	14.41	3.9	0.12	17.65	19
	12/16/03	7.09	14.27	8.1	0.11	13.60	52

Notes:
The values presented in the table are stabilized, final readings during purging.

SU	Standard Units
mg/L	Milligrams per liter; equivalent to parts per million
mV	Millivolts
mS/cm	Microsiemens per centimeter
NTU	Nephelometric turbidity units
°C	Degrees Celsius

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Table 07. Field Parameter Measurements, PSEG Nuclear, LLC, Salem Generating Station, Hancock's Bridge, New Jersey.

Observation Well Identification	Date	pH (SU)	Specific Conductance (mS/cm)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Temperature (°C)	Oxidation-Reduction Potential (mV)
		Parameter					
Well M	04/30/03	7.17	0.42	16.6	7.64	21.34	35
	07/09/03	6.84	0.43	125.0	0.14	28.42	-27
	07/23/03	6.81	0.43	59.0	0.11	28.89	-39
	08/06/03	6.75	0.44	120.0	0.13	30.08	-19
	08/20/03	6.70	0.43	100.0	0.15	30.53	85
	09/04/03	6.72	0.42	134	0.10	30.71	163
	09/16/03	6.72	0.42	71.5	0.25	32.69	197
	10/03/03	6.77	0.43	150.0	0.13	28.53	24
	10/20/03	6.71	0.44	30.5	0.12	27.55	27
	12/04/03	6.85	0.39	22.3	0.11	19.48	95
Well N	04/30/03	5.70	0.37	3.8	2.18	20.14	484
	05/06/03	5.65	0.31	7.9	3.40	19.60	239
	05/21/03	5.90	0.38	6.7	3.25	19.75	194
	05/27/03	5.80	0.35	38.8	3.29	20.23	283
	06/04/03	5.80	0.31	11.1	2.18	20.11	-58
	06/11/03	5.66	0.28	8.1	1.70	21.83	151
	06/19/03	5.63	0.29	25.1	1.24	22.21	194
	06/25/03	5.61	0.30	1.6	1.24	23.06	165
	07/10/03	5.66	0.29	24.8	1.31	24.88	294
	07/25/03	5.70	0.31	2.0	1.63	26.83	120
	08/20/03	5.53	0.31	10.0	1.65	27.89	188
	09/04/03	5.77	3.65	2.0	2.03	27.45	263
	09/17/03	5.81	0.37	3.2	2.88	28.52	330
	10/03/03	5.95	0.405	13.5	3.19	27.42	190
	11/03/03	6.02	0.39	76.1	1.98	25.61	299
	12/12/03	5.92	0.42	6.1	0.79	22.23	86

Notes:
The values presented in the table are stabilized, final readings during purging.

SU	Standard Units
mg/L	Milligrams per liter; equivalent to parts per million
mV	Millivolts
mS/cm	Microsiemens per centimeter
NTU	Nephelometric turbidity units
°C	Degrees Celsius

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Table 07. Field Parameter Measurements, PSEG Nuclear, LLC, Salem Generating Station, Hancock's Bridge, New Jersey.

		Parameter					
Observation Well Identification	Date	pH (SU)	Specific Conductance (mS/cm)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Temperature (°C)	Oxidation-Reduction Potential (mV)
Well O	04/29/03	7.25	0.21	3.5	0.30	16.39	NA
	05/06/03	6.99	0.19	1.8	0.50	16.00	-144
	05/23/03	7.28	0.20	4.9	0.32	18.87	-119
	05/28/03	7.40	0.23	6.5	0.39	17.92	-134
	06/03/03	7.01	0.24	6.1	0.55	18.95	-82
	06/10/03	7.10	0.21	10.6	0.54	20.30	-123
	06/17/03	7.08	0.21	10.2	0.66	20.33	-91
	06/24/03	6.84	0.27	0.0	0.76	22.49	-88
	07/09/03	7.05	0.27	0.0	0.41	23.81	-46
	07/25/03	6.79	0.25	0.0	0.82	25.27	-11
	08/20/03	6.66	0.30	4.6	0.40	27.68	80
	09/03/03	6.96	0.26	0.0	0.74	27.94	42
	09/15/03	7.11	0.26	0.0	0.59	28.50	31
	10/03/03	6.74	0.45	4.9	0.26	26.24	129
	10/20/03	6.58	0.71	0.0	0.28	25.07	-35
	11/17/03	6.68	0.42	3.8	0.21	22.25	-43
	12/18/03	6.20	2.49	2.1	1.40	14.48	290
Well P	04/29/03	6.74	10.39	29.5	0.94	15.16	-40
	05/05/03	6.50	9.94	13.4	0.48	12.90	-175
	05/15/03	6.80	10.50	17.6	0.19	14.68	-166
	05/20/03	6.83	10.38	15.8	0.33	16.22	-178
	05/31/03	6.69	12.30	20.6	0.18	17.00	-137
	06/04/03	6.75	10.84	24.3	0.10	14.25	-181
	06/10/03	6.75	9.78	33.0	0.50	17.43	-165
	06/17/03	6.79	9.98	40.2	0.17	15.72	-176
	06/24/03	6.86	12.29	20.0	0.21	17.44	-181
	07/16/03	6.88	11.91	46.7	0.18	18.44	-120
	08/13/03	6.39	12.29	56.0	0.13	18.38	-105
	09/08/03	6.52	11.78	9.9	0.10	18.29	-76
	10/06/03	6.41	12.38	14.0	0.09	17.22	-96

Notes:
The values presented in the table are stabilized, final readings during purging.

SU	Standard Units
mg/L	Milligrams per liter; equivalent to parts per million
mV	Millivolts
mS/cm	Microsiemens per centimeter
NTU	Nephelometric turbidity units
°C	Degrees Celsius

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Table 07. Field Parameter Measurements, PSEG Nuclear, LLC, Salem Generating Station, Hancock's Bridge, New Jersey.

		Parameter					
Observation Well Identification	Date	pH (SU)	Specific Conductance (mS/cm)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Temperature (°C)	Oxidation-Reduction Potential (mV)
Well Q	04/30/03	6.46	13.69	20.0	0.20	14.55	-48
	05/06/03	6.34	12.01	99.6	0.16	15.30	-123
	05/12/03	6.28	12.43	38.9	0.36	16.56	-76
	05/19/03	6.42	12.61	159	0.12	16.19	-170
	05/30/03	6.35	14.80	173.0	0.22	16.88	-113
	06/05/03	6.43	11.80	15.4	0.17	15.31	-157
	06/11/03	6.35	11.74	12.6	0.14	17.64	-145
	06/16/03	6.48	12.00	16.5	0.16	16.64	-152
	06/23/03	6.24	15.10	8.3	0.18	16.99	-99
	07/17/03	6.39	13.87	11.0	0.31	17.10	-86
	08/13/03	6.25	14.11	14.2	0.14	18.98	-85
	09/10/03	6.14	13.75	11.4	0.09	16.58	13
	10/07/03	6.01	14.44	0.0	0.16	16.61	169
	11/09/03	5.98	14.06	4.2	0.17	13.86	102
Well R	04/30/03	6.74	0.54	15.8	8.02	18.72	33
	07/09/03	8.20	0.60	85	0.12	24.33	-189
	07/25/03	7.30	0.57	21.6	0.12	25.52	-99
	08/06/03	8.11	0.60	145	0.10	26.17	-99
	08/20/03	6.76	0.58	280	0.19	27.13	84
	09/17/03	8.32	0.63	27.3	0.16	26.03	-
	10/03/03	6.66	0.64	19.8	0.12	24.48	178
	10/21/03	6.58	0.65	24.9	0.12	22.86	197
	12/05/03	6.31	0.64	24.8	0.13	15.87	279
Well S	07/09/03	6.89	0.72	5.9	0.12	19.20	-128
	07/21/03	7.05	0.69	9.6	0.13	20.80	-107
	08/07/03	6.58	6.70	32.4	0.08	19.85	-73
	08/21/03	6.92	0.62	-65.0	0.15	21.77	0
	09/15/03	6.58	0.62	23.7	0.10	21.63	-23
	10/04/03	6.29	0.63	40.8	0.13	20.75	61
	10/13/03	6.43	0.67	15.0	0.10	21.11	0
	10/20/03	5.98	0.70	39.0	0.10	19.54	145
	11/09/03	6.42	0.63	13.6	0.11	18.40	-42
	11/26/03	6.57	0.62	64.4	0.28	17.67	278

Notes:
The values presented in the table are stabilized, final readings during purging.

SU	Standard Units
mg/L	Milligrams per liter; equivalent to parts per million
mV	Millivolts
mS/cm	Microsiemens per centimeter
NTU	Nephelometric turbidity units
°C	Degrees Celsius

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Table 07. Field Parameter Measurements, PSEG Nuclear, LLC, Salem Generating Station, Hancock's Bridge, New Jersey.

		Parameter					
Observation Well Identification	Date	pH (SU)	Specific Conductance (mS/cm)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Temperature (°C)	Oxidation-Reduction Potential (mV)
Well T	07/02/03	NA	NA	NA	NA	NA	NA
	07/10/03	6.86	6.35	3.0	0.10	17.80	-149
	07/15/03	6.81	6.34	4.2	0.18	19.07	-101
	07/30/03	6.88	6.43	4.9	0.19	18.52	-92
	08/12/03	6.83	6.41	0.5	0.10	19.99	-100
	08/28/03	6.61	6.27	59.1	0.13	18.85	12
	09/09/03	6.71	6.18	38.9	0.07	19.23	-55
	09/25/03	7.07	6.33	50.0	0.09	19.53	-84
	10/06/03	6.51	6.08	14.6	0.16	18.31	90
	12/12/03	6.51	6.41	69.9	0.06	15.85	-21
Well U	07/02/03	NA	NA	NA	NA	NA	NA
	07/10/03	6.91	1.57	6.7	0.13	16.45	-136
	07/16/03	6.85	1.53	5.6	0.09	17.91	-140
	07/29/03	6.96	1.52	20.8	0.09	17.88	-128
	08/12/03	6.81	1.59	0.4	0.10	18.72	-117
	08/27/03	6.75	1.49	21.0	0.09	19.05	-94
	09/08/03	6.54	1.48	14.1	0.09	17.74	-46
	09/25/03	7.07	1.43	24.9	0.12	18.98	-63
	10/06/03	6.45	1.52	23.1	0.06	17.29	-65
	12/12/03	6.38	1.52	11.0	0.06	14.36	0
Well V	07/02/03	NA	NA	NA	NA	NA	NA
	07/21/03	7.14	3.91	14.9	0.16	19.64	-29
	07/29/03	7.06	3.90	7.2	0.11	18.61	-95
	08/12/03	6.80	3.85	0.0	0.11	18.82	-24
	08/22/03	6.81	3.83	3.5	0.15	19.66	-10
	09/09/03	6.72	3.89	0.0	0.08	18.80	-41
	09/25/03	7.30	4.05	0.6	0.20	18.99	12
	10/06/03	6.65	3.69	0.0	0.07	17.94	-85
	12/12/03	6.51	3.68	1.7	0.09	14.07	14

Notes:
The values presented in the table are stabilized, final readings during purging.

SU	Standard Units
mg/L	Milligrams per liter; equivalent to parts per million
mV	Millivolts
mS/cm	Microsiemens per centimeter
NTU	Nephelometric turbidity units
°C	Degrees Celsius

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Table 07. Field Parameter Measurements, PSEG Nuclear, LLC, Salem Generating Station, Hancock's Bridge, New Jersey.

		Parameter					
Observation Well Identification	Date	pH (SU)	Specific Conductance (mS/cm)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Temperature (°C)	Oxidation-Reduction Potential (mV)
Well W	07/07/03	6.80	2.29	1.0	0.48	19.78	-108
	07/21/03	6.80	2.36	2.0	0.14	20.74	-104
	08/07/03	5.62	0.35	17.0	1.68	26.89	308
	08/19/03	6.73	2.39	8.0	0.12	20.34	-74
	09/03/03	6.63	2.33	3.3	0.10	19.25	-35
	09/15/03	6.72	2.34	0.5	0.13	20.37	-24
	10/03/03	6.53	2.35	2.3	0.11	19.39	45
	10/20/03	6.24	2.67	0.0	0.13	17.81	125
	11/17/03	6.43	2.46	2.6	0.23	17.72	-24
	12/16/03	6.49	2.16	6.0	0.09	15.11	8
Well Y	10/27/03	6.92	7.42	34.2	0.32	16.29	108
	11/09/03	6.55	7.52	3.7	0.67	15.44	259
	11/24/03	6.92	7.49	5.6	0.11	15.73	255
	12/12/03	6.43	7.46	5.8	0.11	13.53	141
	12/22/03	6.33	7.5	11.5	0.09	14.25	186
Well Z	10/27/03	7.10	3.90	42.0	0.08	17.25	-37
	11/09/03	6.71	3.99	28.2	0.58	16.18	206
	11/24/03	7.06	4.00	19.5	0.07	16.21	120
	12/12/03	6.62	3.98	20.6	0.07	14.41	55
	12/22/03	6.51	3.92	9.9	0.09	15.13	76
Well AA	10/27/03	5.74	2.21	53.0	0.08	18.17	10
	11/10/03	5.73	2.24	49.2	0.15	17.79	80
	11/24/03	6.03	2.21	14.7	0.11	17.72	57
	12/10/03	5.02	2.19	18.3	0.16	18.70	236
	12/22/03	4.96	1.96	10.0	0.26	15.54	76
Well AB	10/28/03	6.41	1.79	58.7	0.12	22.95	29
	11/02/03	6.32	1.82	31.9	0.05	23.28	205
	11/17/03	6.13	1.90	16.2	0.14	22.12	17
	12/04/03	6.45	1.85	24.6	0.11	20.04	87
	12/16/03	6.31	1.89	5.1	0.07	19.22	-27
Well AC	10/28/03	6.68	0.45	50.3	0.24	24.61	-16
	11/03/03	6.65	0.43	25.0	0.30	24.38	0.429
	11/18/03	6.39	0.48	12.9	0.17	23.41	-219
	12/05/03	6.52	0.44	38.0	0.27	21.88	304
	12/18/03	6.49	0.44	14.4	0.05	20.25	101

Notes:
The values presented in the table are stabilized, final readings during purging.

SU	Standard Units
mg/L	Milligrams per liter; equivalent to parts per million
mV	Millivolts
mS/cm	Microsiemens per centimeter
NTU	Nephelometric turbidity units
°C	Degrees Celsius

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Table 07. Field Parameter Measurements, PSEG Nuclear, LLC, Salem Generating Station, Hancock's Bridge, New Jersey.

Observation Well Identification	Date	pH (SU)	Specific Conductance (mS/cm)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Temperature (°C)	Oxidation-Reduction Potential (mV)
		Parameter					
Well AD	10/27/03	7.12	1.90	24.0	0.07	20.28	-72
	11/02/03	6.67	1.98	16.3	0.06	21.36	64
	11/17/03	6.52	2.18	21.8	0.22	18.72	15
	12/04/03	6.76	1.60	4.6	0.08	17.69	81
	12/16/03	6.08	1.45	11.1	0.13	17.36	-12
Well AE	10/27/03	6.64	0.27	11.4	0.10	24.98	-60
	11/02/03	6.19	0.25	13.6	0.44	25.18	-60
	11/17/03	6.15	0.25	2.9	0.16	23.64	-25
	12/04/03	6.32	0.23	2.3	0.23	19.83	83
	12/18/03	5.60	0.22	1.6	0.36	17.09	288
Well AF	10/27/03	7.11	4.10	101.0	0.04	20.43	-99
	11/10/03	6.73	3.00	55.4	0.09	19.68	20
	11/24/03	7.01	3.65	9.5	0.07	20.51	-30
	12/13/03	6.39	3.36	21.7	0.11	18.50	238
	12/22/03	6.41	3.36	2.9	0.06	18.19	3
Maximum Measurement		8.32	15.10	280.0	8.02	32.69	484
Minimum Measurement		4.96	0.19	-65.0	0.04	12.50	-219
Average Measurement		6.65	4.73	23.1	0.48	19.58	-4

Notes:
The values presented in the table are stabilized, final readings during purging.

SU Standard Units
mg/L Milligrams per liter; equivalent to parts per million
mV Millivolts
mS/cm Microsiemens per centimeter
NTU Nephelometric turbidity units
°C Degrees Celsius

Table 08. Groundwater Elevations, PSEG Salem Generating Station, Hancock's Bridge, New Jersey.

Screened Interval - Typical (ft bgs)	Monitored Lithologic Unit[1]	Well Identification	Water-Level Elevation (ft rpd) 26-Jun-2003	Water-Level Elevation (ft amsl) 26-Jun-2003	Water-Level Elevation (ft rpd) 28-Jul-2003	Water-Level Elevation (ft amsl) 28-Jul-2003	Water-Level Elevation (ft rpd) 15-Aug-2003	Water-Level Elevation (ft amsl) 15-Aug-2003	Water-Level Elevation (ft rpd) 14-Oct-2003	Water-Level Elevation (ft amsl) 14-Oct-2003	Water-Level Elevation (ft rpd) 6-Nov-2003	Water-Level Elevation (ft amsl) 6-Nov-2003	Water-Level Elevation (ft rpd) 20-Feb-2004	Water-Level Elevation (ft amsl) 20-Feb-2004
10 to 20	Shallow, Water-Bearing Unit (Inside the Limits of Cofferdam)	Well M	95.11	5.19	94.56	4.64	94.74	4.82	93.58	3.66	93.37	3.45	93.51	3.59
		Well N	94.33	4.41	93.55	3.63	93.73	3.81	93.00	3.08	92.76	2.84	92.29	2.37
		Well O	95.17	5.25	94.50	4.58	94.79	4.87	93.45	3.53	93.57	3.65	92.47	2.55
		Well R	96.50	6.58	95.86	5.94	96.04	6.12	94.44	4.52	94.65	4.73	94.84	4.92
		Well AC	--	--	--	--	--	--	93.01	3.09	92.82	2.90	NM	NM
		Well AE	--	--	--	--	--	--	93.15	3.23	94.32	4.40	92.13	2.21
		Well AI	--	--	--	--	--	--	--	--	--	--	92.21	2.29
		Mean	**95.28**	**5.36**	**94.62**	**4.70**	**94.83**	**4.91**	**93.44**	**3.52**	**93.58**	**3.66**	**92.91**	**2.99**
25 to 35	Shallow, Water-Bearing Unit (Outside the Limits of Cofferdam)	Well S	92.95	3.03	92.46	2.54	92.54	2.62	92.44	2.52	92.10	2.18	91.57	1.65
		Well T	92.95	3.03	92.66	2.74	92.62	2.70	92.74	2.82	92.06	2.14	91.76	1.84
		Well U	93.20	3.28	92.85	2.93	92.82	2.90	92.79	2.87	92.14	2.22	91.87	1.95
		Well W	92.86	2.94	92.41	2.49	92.41	2.49	92.29	2.37	91.79	1.87	91.41	1.49
		Well Y	--	--	--	--	--	--	92.09	2.17	91.68	1.76	91.19	1.27
		Well Z	--	--	--	--	--	--	92.07	2.15	91.70	1.78	91.13	1.21
		Well AA	--	--	--	--	--	--	91.97	2.05	91.57	1.65	91.08	1.16
		Well AB	--	--	--	--	--	--	92.31	2.39	92.03	2.11	91.53	1.61
		Well AD	--	--	--	--	--	--	92.17	2.25	91.80	1.88	91.24	1.32
		Well AF	--	--	--	--	--	--	92.18	2.26	91.80	1.88	91.23	1.31
		Well AG (Shallow)	--	--	--	--	--	--	--	--	--	--	90.92	1.00
		Well AG (Deep)	--	--	--	--	--	--	--	--	--	--	90.85	0.93
		Well AH (Shallow)	--	--	--	--	--	--	--	--	--	--	90.45	0.53
		Well AH (Deep)	--	--	--	--	--	--	--	--	--	--	90.71	0.79
		Well AJ	--	--	--	--	--	--	--	--	--	--	91.40	1.48
		Well AL	--	--	--	--	--	--	--	--	--	--	93.11	3.19
		Well AM	--	--	--	--	--	--	--	--	--	--	92.30	2.38
		Mean	**92.99**	**3.07**	**92.60**	**2.68**	**92.60**	**2.68**	**92.31**	**2.39**	**91.87**	**1.95**	**91.40**	**1.48**
70 to 80	Vincentown Formation	Well K	91.36	1.44	90.98	1.06	90.84	0.92	91.90	1.98	90.12	0.20	NM	NM
		Well L	91.35	1.43	90.61	0.69	90.54	0.62	92.42	2.50	91.91	1.99	NM	NM
		Well P	91.32	1.40	90.67	0.75	90.37	0.45	92.55	2.63	93.23	3.31	NM	NM
		Well Q	91.29	1.37	89.90	-0.02	91.08	1.16	91.51	1.59	91.18	1.26	NM	NM
		Well V	91.58	1.66	91.08	1.16	90.92	1.00	92.00	2.08	91.32	1.40	NM	NM
		Mean	**91.38**	**1.46**	**90.65**	**0.73**	**90.75**	**0.83**	**92.08**	**2.16**	**91.55**	**1.63**	**NM**	**NM**

Notes

1	Lithologic units correspond with those outlined on cross sections A-A' through E-E'. The shallow, water-bearing unit consists of the structural and hydraulic fill and the riverbed deposits. The shallow, water-bearing unit is separated from the Vincentown Formation by the Kirkwood Formation.
--	Monitoring well not installed at the time of the water level gauging event.
NM	Water level measurement not collected.
ft bgs	Feet below ground surface.
ft rpd	Elevation (in feet) relative to plant datum.
ft amsl	Feet above mean sea level (NAVD 1988).
	Mean tide level at Artificial Island is 0.11 feet (NAVD 1988).

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Table09. Summary of Field Observations - Aquifer Pumping Tests, PSEG Nuclear, LLC, Salem Generating Station, Hancock's Bridge, New Jersey.

Well ID	Date of Test	Test No.	Total Depth of Well (ft) [2]	Depth to Static Water Level (ft) [2]	Duration of Pumping Phase of Test (min)	Approximate Discharge Rates (gpm)	Duration of Discharge Rate (min)	Maximum Displacment at Specified Rate (ft)	Radius of well (in)	Volume of Well (gal) [3]	Volume of Water Produced (gal)
AM[1]	2/4/2004	1	20.9	6.74	140	0.25 0.5	80 60	5.4 12.3	0.17	48.5	40
AM[1]	2/4/2004	2	20.9	7.5	62	0.33	62	9.1	0.17	45.9	18
S	2/2/2004	1	37.2	11.83	305	0.25	305	19.9	0.08	74.6	77
AC	2/4/2004	1	27	9.64	283	0.25 0.5 0.75	78 174 31	2.3 6.4 10.3	0.08	51.0	116
AJ[1]	2/2/2004	1	35.3	8.16	275	0.25 0.5	148 127	7.3 23.2	0.17	93.0	75
AI[1]	2/3/2004	1	22	10.63	315	0.25 0.5 0.75	80 175 60	3.3 6.6 11.6	0.17	38.9	145
AD	1/30/2004	1	45.5	10.44	331	0.25 0.5	205 126	8.6 17.0	0.25	148.1	85
AB	1/29/2004	1	44.5	11.1	304	0.25 0.5 1 2	60 70 94 80	1.5 3.3 6.2 16.0	0.08	98.2	280

Notes:

[1] Well not completed, top of well approximately at land surface.

[2] From measuring point, approximately 2.5 feet above land surface.

[3] included volume of gravel pack

ft = feet

gal = gallons

Table 10. Slug Test Results, PSEG Nuclear, LLC, Salem Generating Station, Hancock's Bridge, New Jersey.

Well Identification	Monitored Lithologic Unit[1]	Test Type	Hydraulic Conductivity Results (ft/day)	Hydraulic Conductivity Results (cm/s)
Well N	Engineered Fill (10 to 20 ft bgs)	Falling Head Rising Head	0.144 0.0928	5.07×10^{-5} 3.28×10^{-5}
Well O	Engineered Fill (10 to 20 ft bgs)	Falling Head Rising Head	3.62 4.26	1.28×10^{-3} 1.50×10^{-3}
Well U	Vincentown formation (70 to 80 ft bgs)	Falling Head Rising Head	2.95 NA	1.04×10^{-3} NA

Notes

1	*Lithologic units correspond with those outlined on cross sections A-A' through E-E'.*
ft/day	Feet per day.
cm/s	Centimeters per second.
ft bgs	Feet below ground surface.
NA	Data not available. Test not performed

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Table 11. Summary of Aquifer Pumping Test Results, PSEG Nuclear, LLC, Salem Generating Station, Hancock's Bridge, New Jersey.

		Pumping		Recovery	
Well ID	Date of Test	Transmissivity (ft^2/day)	Hydraulic Conductivity (ft/day)	Transmissivity (ft^2/day)	Hydraulic Conductivity (ft/day)
AM[1]	2/4/2004	1.403	0.14	0.572	0.06
AM[2]	2/4/2004	1.079	0.11	0.338	0.03
S	2/2/2004	1.701	0.17	1.096	0.11
AC	2/4/2004	12.63	1.26	1.672	0.17
AJ	2/2/2004	1.73	0.09	0.56	0.03
AI	2/3/2004	7.97	0.80	2.101	0.21
AD	1/30/2004	0.942	0.09	0.937	0.09
AB	1/29/2004	27.67	2.77	22.69	2.27

Notes:

[1] Results of the step drawdown test.

[2] Results of the constant rate test.

ft^2/day = square feet per day.

ft/day - feet per day.

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Table 12. Groundwater Analytical Results, PSEG Nuclear, LLC, Salem Generating Station, Hancock's Bridge, New Jersey.

Well Identification	Sample Date	Tritium (pCi/L)	Major Cations and Anions		Gamma-Emmitting Isotopes (pCi/L)				
			Boron (ug/L)	Sodium (mg/L)	Potassium-40	Radium-Natural	Thorium-232	Thorium-234	Uranium-235
K [1]	02/05/03	1,120	738	1,060	82.4	23.7	<6.51	<50.4	4.90
K [2]	02/05/03	1,070	--	--	--	--	--	--	--
K	02/12/03	506	557	727	--	--	--	--	--
K	02/27/03	1,170	803	1,210	<20.4	9.24	<9.31	128	5.76
K	03/14/03	937	1,380	1,200	--	--	--	--	--
K	03/18/03	875	1,190	1,060	--	--	--	--	--
K	03/26/03	822	966	1,070	--	--	--	--	--
K	03/31/03	677	1,150	1,190	--	--	--	--	--
K	04/09/03	1,010	1,290	1,290	--	--	--	--	--
K	04/17/03	1,170	1,160	1,370	--	--	--	--	--
K	04/21/03	911	--	1,240	--	--	--	--	--
K	04/29/03	833	--	1,240	--	--	--	--	--
K	05/05/03	948	--	1,210	--	--	--	--	--
K	05/20/03	878	1,240	1,200	--	--	--	--	--
K	05/28/03	859	1,020	1,210	--	--	--	--	--
K	06/04/03	921	980	1,240	--	--	--	--	--
K	06/10/03	897	1,260	1,260	--	--	--	--	--
K	06/17/03	894	1,040	1,220	--	--	--	--	--
K	06/24/03	783	1,080	1,250	--	--	--	--	--
K	06/30/03	914	1,190	1,300	61.0	<1.31	<4.40	241	6.06
K	07/16/03	870	1,140	1,300	<13.6	6.24	<4.81	<59.6	8.23
K	07/29/03	950	988	1,240	<18.1	<3.93	<6.81	166	5.57
K	08/12/03	845	1,130	1,190	57.4	<4.62	<3.61	132	5.82
K	08/27/03	852	1,020	1,220	41.3	<2.15	<5.16	160	4.79
K	09/09/03	653	1,160	1,170	<21.4	<2.69	<6.02	<80.0	<5.50
K	09/25/03	713	816	1,280	57.6	<3.13	<4.69	135	<4.87
K	10/06/03	880	1,150	1,250	--	--	--	--	--
K	11/09/03	891	919	1,330	--	--	--	--	--

Notes:

ug/L	Micrograms per liter
mg/L	Milligrams per liter
pCi/L	Picocuries per liter
1,120	Constituent was detected above the laboratory method detection limit.
<20.4	Constituent was not detected above the laboratory detection limit.
--	Constituent not analyzed.
1	Grab groundwater sample collected during monitoring well installation.
2	Samples were re-analyzed to compare results.

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Table 12. Groundwater Analytical Results, PSEG Nuclear, LLC, Salem Generating Station, Hancock's Bridge, New Jersey.

Well Identification	Sample Date	Tritium (pCi/L)	Major Cations and Anions		Gamma-Emmitting Isotopes (pCi/L)				
			Boron (ug/L)	Sodium (mg/L)	Potassium-40	Radium-Natural	Thorium-232	Thorium-234	Uranium-235
L [1]	01/27/03	<151	**533**	**1,900**	--	--	--	--	--
L	03/14/03	<143	--	--	--	--	--	--	--
L	03/18/03	<143	--	--	--	--	--	--	--
L	03/26/03	<141	--	--	--	--	--	--	--
L	04/02/03	<153	**2,170**	**2,260**	--	--	--	--	--
L	04/08/03	<142	--	--	--	--	--	--	--
L	04/15/03	<141	--	--	--	--	--	--	--
L	04/24/03	<139	--	--	--	--	--	--	--
L	04/29/03	<141	--	--	--	--	--	--	--
L	05/05/03	<134	--	--	--	--	--	--	--
L	05/15/03	<144	--	--	--	--	--	--	--
L	05/20/03	<144	--	--	--	--	--	--	--
L	05/28/03	<141	--	--	--	--	--	--	--
L	06/04/03	<140	--	--	--	--	--	--	--
L	06/10/03	<137	--	--	--	--	--	--	--
L	06/17/03	<141	--	--	--	--	--	--	--
L	06/24/03	<141	--	--	--	--	--	--	--
L	06/30/03	<140	**2,080**	**2,490**	<95.3	<5.55	<19.1	**447**	**12.3**
L	07/29/03	<141	**1,860**	**2,360**	<9.99	**6.47**	<5.08	**264**	**9.55**
L	08/27/03	<142	**1,950**	**2,330**	--	--	--	--	--
L	09/25/03	<140	**1,620**	**2,490**	--	--	--	--	--
L	12/16/03	<146	--	--	--	--	--	--	--
M [1]	02/12/03	**18,700**	**252**	**23.0**	**146**	**12.9**	<13.3	<43.2	**7.10**
M	02/28/03	**14,400**	**168**	**27.7**	**64.7**	<2.84	<6.48	**123**	<1.22
M	03/03/03	**9,420**	**164**	**26.6**	**62.7**	<2.44	<4.54	<42.8	<2.90
M	03/10/03	**15,000**	**234**	**23.6**	--	--	--	--	--
M	03/17/03	**10,600**	**207**	**22.2**	--	--	--	--	--
M	03/24/03	**10,100**	**171**	**26.3**	--	--	--	--	--
M	03/31/03	**11,000**	**161**	**23.1**	--	--	--	--	--
M	04/07/03	**9,260**	**177**	**24.3**	--	--	--	--	--
M	04/14/03	**9,600**	**186**	**23.9**	--	--	--	--	--

Notes:

ug/L Micrograms per liter

mg/L Milligrams per liter

pCi/L Picocuries per liter

18,700 Constituent was detected above the laboratory method detection limit.

<141 Constituent was not detected above the laboratory detection limit.

-- Constituent not analyzed.

[1] Grab groundwater sample collected during monitoring well installation.

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Table 12. Groundwater Analytical Results, PSEG Nuclear, LLC, Salem Generating Station, Hancock's Bridge, New Jersey.

Well Identification	Sample Date	Tritium (pCi/L)	Major Cations and Anions		Gamma-Emmitting Isotopes (pCi/L)				
			Boron (ug/L)	Sodium (mg/L)	Potassium-40	Radium-Natural	Thorium-232	Thorium-234	Uranium-235
M[3]	04/21/03	8,880	--	22.5	--	--	--	--	--
M[3]	04/30/03	8,800	--	23.7	--	--	--	--	--
M[3]	07/09/03	126,000	307	20.8	<23.7	43.9	<3.70	<83.2	<4.13
M	07/23/03	113,000	234	22.0	78.1	<2.97	<7.30	<82.4	<4.52
M	08/06/03	73,200	242	21.9	53.1	16.1	<4.38	<38.9	<2.88
M	08/20/03	62,000	274	22.5	48.1	<2.17	<4.08	169	<4.31
M	09/04/03	35,300	222	22.8	63.2	12.7	<4.48	178	<337
M	09/16/03	28,400	320	24.5	47.7	7.26	<3.97	<148	<412
M	10/03/03	25,400	266	25.0	49.0	11.8	<4.46	116	<479
M	10/20/03	16,380	--	--	--	--	--	--	--
M	12/04/03	9,010	--	--	--	--	--	--	--
M	01/06/04	11,400	--	--	--	--	--	--	--
N[1]	01/30/03	69,000	339	14.3	<41.2	32	<5.25	<38.4	<3.37
N[2]	01/30/03	58,400	370	14.4	--	--	--	--	--
N	02/10/03	15,600	276	10.6	--	--	--	--	--
N	03/04/03	2,770	197	34.3	62.5	43.9	<7.23	<47.0	4.99
N	03/14/03	2,670	408	24.0	--	--	--	--	--
N	03/17/03	3,830	362	20.5	--	--	--	--	--
N	03/25/03	3,480	238	18.1	--	--	--	--	--
N	04/04/03	3,560	210	19.6	--	--	--	--	--
N	04/11/03	3,730	249	19.3	--	--	--	--	--
N	04/16/03	3,910	228	22.2	--	--	--	--	--
N	04/25/03	4,600	--	16.2	--	--	--	--	--
N	04/30/03	9,370	--	15.8	--	--	--	--	--
N	05/06/03	9,830	--	19.8	--	--	--	--	--
N	05/21/03	7,480	299	19.2	--	--	--	--	--
N	05/27/03	7,130	225	17.6	--	--	--	--	--
N	06/04/03	5,480	233	20.0	--	--	--	--	--
N	06/11/03	4,990	304	19.8	--	--	--	--	--

Notes:

ug/L	Micrograms per liter
mg/L	Milligrams per liter
pCi/L	Picocuries per liter
18,700	Constituent was detected above the laboratory method detection limit.
<141	Constituent was not detected above the laboratory detection limit.
--	Constituent not analyzed.
1	Grab groundwater sample collected during monitoring well installation.
2	Samples were re-analyzed to compare results.
3	Well M was replaced in May 2003 with a properly constructed Monitoring Well. Prior to this, Well M was installed as a temporary well constructed with mill-slotted steel

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Table 12. Groundwater Analytical Results, PSEG Nuclear, LLC, Salem Generating Station, Hancock's Bridge, New Jersey.

Well Identification	Sample Date	Tritium (pCi/L)	Major Cations and Anions		Gamma-Emmitting Isotopes (pCi/L)				
			Boron (ug/L)	Sodium (mg/L)	Potassium-40	Radium-Natural	Thorium-232	Thorium-234	Uranium-235
N	06/19/03	**5,680**	**217**	**18.4**	--	--	--	--	--
N	06/25/03	**5,060**	**268**	**17.1**	--	--	--	--	--
N	07/10/03	**5,020**	**268**	**17.5**	<21.1	**5.37**	<4.48	<64.5	**8.10**
N	07/25/03	**5,220**	**217**	**19.6**	<13.0	<2.38	<4.19	**153**	<4.52
N	08/07/03	**5,110**	**210**	**23.5**	<15.4	**14.7**	<4.70	<93.5	**11.0**
N	08/20/03	**5,850**	**247**	**20.4**	<9.32	<2.41	<4.00	<160	<4.06
N	09/04/03	**5,660**	**334**	**22.8**	<16.1	<1.75	<4.54	<52.9	3.96
N	09/17/03	**6,160**	**267**	**22.4**	**67.9**	<2.51	<5.90	<57.1	<4.81
N	10/03/03	**5,740**	**240**	**24.0**	<31.7	**6.37**	<3.87	166	<1.25
N	11/03/03	**5,560**	--	--	--	--	--	--	--
N	12/12/03	**6,010**	--	--	--	--	--	--	--
N	01/20/04	**6,460**	--	--	--	--	--	--	--
O [1]	01/29/03	**1,220**	**156**	**40.5**	**930**	**62.9**	**88.5**	**177**	**16.5**
O [2]	01/29/03	**1,400**	**172**	**40.4**	--	--	--	--	--
O	02/10/03	**10,300**	**97**	**13.2**	--	--	--	--	--
O	02/21/03	**7,370**	**89**	**15.4**	--	--	--	--	--
O	02/28/03	**11,700**	**89**	**17.0**	<14.8	9.12	<6.97	**120**	**4.04**
O	03/04/03	**8,800**	**71**	**20.8**	--	--	--	--	--
O	03/13/03	**12,300**	**108**	**15.5**	--	--	--	--	--
O	03/17/03	**11,000**	**83**	**11.9**	--	--	--	--	--
O	03/25/03	**8,660**	**98**	**11.7**	--	--	--	--	--
O	03/31/03	**8,010**	**64**	**13.9**	--	--	--	--	--
O	04/07/03	**7,290**	**77**	**8.8**	--	--	--	--	--
O	04/15/03	**12,400**	**85**	**10.0**	--	--	--	--	--
O	04/21/03	**11,800**	--	**11.5**	--	--	--	--	--
O	04/29/03	**10,500**	--	**12.3**	--	--	--	--	--
O	05/06/03	**10,200**	--	**11.2**	--	--	--	--	--
O	05/21/03	**11,100**	**108**	**10.3**	--	--	--	--	--
O	05/28/03	**12,700**	**183**	**11.9**	--	--	--	--	--

Notes:

ug/L	Micrograms per liter
mg/L	Milligrams per liter
pCi/L	Picocuries per liter
12,400	Constituent was detected above the laboratory method detection limit.
<16.1	Constituent was not detected above the laboratory detection limit.
--	Constituent not analyzed.
1	Grab groundwater sample collected during monitoring well installation.
2	Samples were re-analyzed to compare results.

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Table 12. Groundwater Analytical Results, PSEG Nuclear, LLC, Salem Generating Station, Hancock's Bridge, New Jersey.

Well Identification	Sample Date	Tritium (pCi/L)	Major Cations and Anions		Gamma-Emmitting Isotopes (pCi/L)				
			Boron (ug/L)	Sodium (mg/L)	Potassium-40	Radium-Natural	Thorium-232	Thorium-234	Uranium-235
O	06/08/03	**12,200**	**140**	**13.5**	--	--	--	--	--
O	06/10/03	**12,800**	**183**	**14.3**	--	--	--	--	--
O	06/17/03	**10,300**	**204**	**14.9**	--	--	--	--	--
O	06/24/03	**13,400**	**252**	**14.7**	--	--	--	--	--
O	07/09/03	**9,100**	**272**	**14.6**	<21.2	<2.66	<6.62	<123	<3.43
O	07/25/03	**7,710**	**234**	**13.5**	<37.8	**6.34**	<4.13	<199	**3.95**
O	08/06/03	**8,300**	**240**	**14.4**	**39.2**	**10.8**	<4.26	<148	<4.13
O	08/20/03	**7,440**	**305**	**13.9**	<16.4	<2.58	<3.82	**164**	<4.31
O	09/03/03	**6,400**	**282**	**13.5**	**46.2**	<2.58	<3.82	**164**	<4.31
O	09/15/03	**5,110**	**270**	**12.9**	<2.62	**6.13**	<6.96	**58.2**	<3.52
O	10/03/03	**6,980**	**233**	**23.2**	**4.30**	**10.7**	<3.55	<92.9	<3.45
O	10/20/03	**6,700**	**201**	**47.0**	--	--	--	--	--
O	12/18/03	**7,060**	--	--	--	--	--	--	--
P [1]	02/06/03	<153	--	--	--	--	--	--	--
P	02/21/03	<148	--	--	--	--	--	--	--
P	03/13/03	**303**	**417**	**1,080**	--	--	--	--	--
P	03/18/03	**465**	**199**	**699**	--	--	--	--	--
P	03/26/03	<143	**336**	**698**	--	--	--	--	--
P	04/03/03	<154	**241**	**1,110**	--	--	--	--	--
P	04/24/03	<139	--	--	--	--	--	--	--
P	04/29/03	<144	--	--	--	--	--	--	--
P	05/05/03	<134	--	--	--	--	--	--	--
P	05/20/03	<145	--	--	--	--	--	--	--
P	05/30/03	<142	--	--	--	--	--	--	--
P	06/04/03	<141	--	--	--	--	--	--	--
P	06/10/03	<138	--	--	--	--	--	--	--
P	06/17/03	<141	--	--	--	--	--	--	--
P	06/24/03	<141	--	--	--	--	--	--	--
P	07/16/03	<141	**485**	**1,580**	**60.7**	<3.56	<5.04	**127**	**3.46**
P	08/13/03	<140	**480**	**1,570**	**47.5**	**3.21**	<4.54	<1.98	<4.34
P	09/09/03	<147	**645**	**1,560**	**63.8**	**11.8**	**6.19**	**54.8**	<5.02
P	10/06/03	<143	**481**	**1,610**	--	--	--	--	--

Notes:

ug/L	Micrograms per liter
mg/L	Milligrams per liter
pCi/L	Picocuries per liter
303	Constituent was detected above the laboratory method detection limit.
<3.56	Constituent was not detected above the laboratory detection limit.
--	Constituent not analyzed.
1	Grab groundwater sample collected during monitoring well installation.

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Table 12. Groundwater Analytical Results, PSEG Nuclear, LLC, Salem Generating Station, Hancock's Bridge, New Jersey.

Well Identification	Sample Date	Tritium (pCi/L)	Major Cations and Anions		Gamma-Emmitting Isotopes (pCi/L)				
			Boron (ug/L)	Sodium (mg/L)	Potassium-40	Radium-Natural	Thorium-232	Thorium-234	Uranium-235
Q	03/14/03	<143	--	--	--	--	--	--	--
Q	03/19/03	<143	--	--	--	--	--	--	--
Q	03/24/03	<143	--	--	--	--	--	--	--
Q	04/23/03	<139	--	--	--	--	--	--	--
Q	04/30/03	<142	--	--	--	--	--	--	--
Q	05/06/03	<135	--	--	--	--	--	--	--
Q	05/12/03	<144	--	--	--	--	--	--	--
Q	05/19/03	<144	--	--	--	--	--	--	--
Q	05/30/03	<140	--	--	--	--	--	--	--
Q	06/05/03	<139	--	--	--	--	--	--	--
Q	06/11/03	<138	--	--	--	--	--	--	--
Q	06/16/03	<141	--	--	--	--	--	--	--
Q	06/23/03	<143	--	--	--	--	--	--	--
Q	07/17/03	<141	**340**	**2,100**	**151**	<5.78	<13.9	<88.4	**8.99**
Q	08/13/03	<142	**315**	**1,830**	85.7	5.63	<4.09	<7.45	<3.06
Q	09/10/03	<148	**247**	**1,790**	86.8	30.2	<5.42	98.1	5.53
Q	10/07/03	<144	**331**	**1,920**	--	--	--	--	--
Q	11/09/03	<142	**317**	**1,930**	--	--	--	--	--
R [1,2]	02/26/03	**13,900**	**288**	**42.6**	**258**	**15.0**	<8.58	**122**	**7.49**
R [2]	03/03/03	**7,490**	**229**	**37.3**	**80.5**	**7.37**	<8.73	**144**	**5.75**
R [2]	03/10/03	**6,170**	**270**	**28.7**	--	--	--	--	--
R [2]	03/17/03	**7,270**	**269**	**33.4**	--	--	--	--	--
R [2]	03/25/03	**6,810**	**248**	**32.4**	--	--	--	--	--
R [2]	04/01/03	**6,740**	**216**	**34.8**	--	--	--	--	--
R [2]	04/08/03	**5,940**	**251**	**33.3**	--	--	--	--	--
R [2]	04/14/03	**5,890**	**255**	**33.4**	--	--	--	--	--
R [2]	04/22/03	**5,800**	--	**32.6**	--	--	--	--	--
R [2]	04/30/03	**5,260**	--	**31.8**	--	--	--	--	--
R	07/09/03	**3,270**	**511**	**57.4**	**58.2**	**33.4**	<4.73	<36.6	<3.18

Notes:

ug/L	Micrograms per liter
mg/L	Milligrams per liter
pCi/L	Picocuries per liter
6,740	Constituent was detected above the laboratory method detection limit.
<4.73	Constituent was not detected above the laboratory detection limit.
--	Constituent not analyzed.
1	Grab groundwater sample collected during monitoring well installation.
2	Well R was replaced in May 2003 with a properly constructed Monitoring Well. Prior to this, Well R was installed as a temporary well constructed with mill-slotted steel

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Table 12. Groundwater Analytical Results, PSEG Nuclear, LLC, Salem Generating Station, Hancock's Bridge, New Jersey.

Well Identification	Sample Date	Tritium (pCi/L)	Major Cations and Anions		Gamma-Emmitting Isotopes (pCi/L)				
			Boron (ug/L)	Sodium (mg/L)	Potassium-40	Radium-Natural	Thorium-232	Thorium-234	Uranium-235
R	07/25/03	2,940	403	48.7	<14.2	<2.40	<4.91	226	<3.98
R	08/06/03	2,860	457	53.6	52.2	14.0	<4.29	112	<4.03
R	08/20/03	2,861	505	48.1	92.1	<2.46	<5.91	<78.0	<3.43
R	09/04/03	2,987	567	45.6	<18.0	6.2	<4.20	<78.7	<2.61
R	09/17/03	2,797	472	49.6	59.3	5.8	<4.48	139	<4.35
R	10/03/03	2,740	402	51.8	61.6	11.8	<4.51	<49.7	<2.92
R	10/21/03	2,650	--	--	--	--	--	--	--
R	12/05/03	2,550	367	49.9	--	--	--	--	--
S	07/09/03	3,530,000	57,400	67.0	<19.4	52.0	<5.06	<50.6	<9.62
S[2]	07/09/03	3,450,000	--	--	--	--	--	--	--
S	08/07/03	2,920,000	--	--	--	--	--	--	--
S	08/21/03	2,570,000	--	--	--	--	--	--	--
S	09/03/03	2,390,000	--	--	--	--	--	--	--
S	09/15/03	2,340,000	--	--	--	--	--	--	--
S	10/04/03	2,180,000	--	--	--	--	--	--	--
S	10/13/03	2,030,000	--	--	--	--	--	--	--
S	10/20/03	2,060,000	--	--	--	--	--	--	--
S	11/09/03	1,960,000	--	--	--	--	--	--	--
S	11/26/03	2,660,000	--	--	--	--	--	--	--
S	01/20/04	1,420,000	--	--	--	--	--	--	--
T	07/10/03	<147	680	1,040	51.0	87.7	<4.67	111	<1.53
T	07/15/03	<140	645	1,150	63.4	43.2	<7.56	<114	<3.85
T	07/30/03	<141	601	969	72.3	<3.41	<4.49	<49.8	<3.33
T	08/12/03	<140	637	931	59.7	3.67	<4.38	<91.2	<3.01
T	08/28/03	<141	660	896	73.3	11.4	<4.31	121	6.17
T	09/09/03	<147	633	899	75.5	18.7	<4.40	184	<3.61
T	09/25/03	<142	633	912	<3.94	7.35	<5.87	<68.3	<5.08
T	10/06/03	<146	650	966	--	--	--	--	--
T	12/12/03	<149	--	--	--	--	--	--	--

Notes:

ug/L	Micrograms per liter
mg/L	Milligrams per liter
pCi/L	Picocuries per liter
680	Constituent was detected above the laboratory method detection limit.
<3.41	Constituent was not detected above the laboratory detection limit.
--	Constituent not analyzed.
2	Samples were re-analyzed to compare results.

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Table 12. Groundwater Analytical Results, PSEG Nuclear, LLC, Salem Generating Station, Hancock's Bridge, New Jersey.

Well Identification	Sample Date	Tritium (pCi/L)	Major Cations and Anions		*Gamma-Emmitting Isotopes (pCi/L)*				
			Boron (ug/L)	Sodium (mg/L)	Potassium-40	Radium-Natural	Thorium-232	Thorium-234	Uranium-235
U	07/10/03	<136	**389**	**178**	**88.4**	**13.6**	<7.18	<48.6	<4.55
U	07/16/03	**146**	**380**	**175**	**77.4**	**14.5**	<4.56	<35.2	<4.01
U	07/29/03	<141	**421**	**146**	**53.2**	<3.09	<4.05	**153**	<3.90
U	08/12/03	<139	**341**	**139**	**64.6**	<2.13	<4.65	**201**	<1.16
U	08/27/03	<143	**347**	**144**	<43.3	**4.20**	<4.55	<136	<3.62
U	09/09/03	**148**	**376**	**139**	<36.8	<3.97	<4.60	**107**	**5.30**
U	09/25/03	<139	**335**	**155**	<23.3	<1.79	<4.58	<46.9	<3.59
U	10/06/03	**203**	**354**	**140**	--	--	--	--	--
U	12/12/03	<148	--	--	--	--	--	--	--
V	07/21/03	**334**	**489**	**609**	**43.0**	<1.86	<4.01	<5.68	<2.78
V	07/29/03	**285**	**431**	**592**	**47.4**	<3.26	<4.71	**164**	<4.63
V	08/12/03	**278**	**495**	**568**	**39.0**	<1.60	<3.95	<143	<2.47
V	08/27/03	**338**	**607**	**584**	<16.8	<1.81	<3.97	<53.3	<3.21
V	09/09/03	**337**	**571**	**582**	<15.7	<4.35	<4.06	**116**	**5.23**
V	09/25/03	**261**	**472**	**670**	<43.5	<1.79	<4.30	**171**	**4.65**
V	10/06/03	**185**	**463**	**543**	--	--	--	--	--
V	11/19/03	**549**	--	--	--	--	--	--	--
V	12/12/03	**207**	--	--	--	--	--	--	--
W	07/07/03	**10,500**	**490**	**220**	<15.9	**9.51**	<3.36	**98.2**	<4.56
W	07/21/03	**11,100**	**491**	**227**	**67.7**	<1.73	<3.11	<59.0	<2.65
W	08/06/03	**11,500**	**464**	**211**	**74.2**	<2.78	<7.46	<94.1	<4.62
W	08/07/03	**6,010**	--	--	--	--	--	--	--
W	08/19/03	**7,660**	**591**	**215**	60.1	<2.43	<5.86	<135	<5.29
W	09/03/03	**8,110**	**533**	**222**	<45.1	<1.76	<3.82	111	5.80
W	09/15/03	**8,710**	**566**	**237**	55.2	<2.43	<4.33	158	<1.23
W	10/03/03	**11,100**	**455**	**240**	<68.1	<3.82	<6.46	<51.9	<5.91
W	10/21/03	**8,260**	--	--	--	--	--	--	--
W	11/17/03	**12,200**	--	--	--	--	--	--	--
W	11/19/03	**13,200**	--	--	--	--	--	--	--
W	12/16/03	**15,500**	--	--	--	--	--	--	--
W	01/14/04	**11,400**	--	--	--	--	--	--	--

Notes:

mg/L	Milligrams per liter
pCi/L	Picocuries per liter
10,500	Constituent was detected above the laboratory method detection limit.
<148	Constituent was not detected above the laboratory detection limit.
--	Constituent not analyzed.

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Table 12. Groundwater Analytical Results, PSEG Nuclear, LLC, Salem Generating Station, Hancock's Bridge, New Jersey.

Well Identification	Sample Date	Tritium (pCi/L)	Major Cations and Anions		Gamma-Emmitting Isotopes (pCi/L)				
			Boron (ug/L)	Sodium (mg/L)	Potassium-40	Radium-Natural	Thorium-232	Thorium-234	Uranium-235
Y	10/27/03	<142	--	--	--	--	--	--	--
Y	11/09/03	<143	--	--	--	--	--	--	--
Y	11/19/03	<3,750	--	--	--	--	--	--	--
Y	11/25/03	<141	**822**	**1,070**	--	--	--	--	--
Y	12/12/03	<148	--	--	--	--	--	--	--
Y	12/22/03	<147	--	--	--	--	--	--	--
Z	10/27/03	**573**	--	--	--	--	--	--	--
Z	11/09/03	<140	--	--	--	--	--	--	--
Z	11/19/03	**729**	--	--	--	--	--	--	--
Z	11/24/03	**583**	**498**	**519**	--	--	--	--	--
Z	12/12/03	**621**	--	--	--	--	--	--	--
Z	12/22/03	**659**	--	--	--	--	--	--	--
AA	10/27/03	**613**	--	--	--	--	--	--	--
AA	11/10/03	**645**	--	--	--	--	--	--	--
AA	11/19/03	**734**	--	--	--	--	--	--	--
AA	11/24/03	**639**	**247**	**253**	--	--	--	--	--
AA	12/10/03	**785**	--	--	--	--	--	--	--
AA	12/22/03	**682**	--	--	--	--	--	--	--
AA	01/06/04	**713**	--	--	--	--	--	--	--
AB	10/28/03	**292,000**	--	--	--	--	--	--	--
AB	11/02/03	**280,000**	--	--	--	--	--	--	--
AB	11/19/03	**321,000**	--	--	--	--	--	--	--
AB	12/04/03	**409,000**	--	--	--	--	--	--	--
AB	12/16/03	**396,000**	--	--	--	--	--	--	--
AB	01/14/03	**281,000**	--	--	--	--	--	--	--

Notes:

mg/L	Milligrams per liter
pCi/L	Picocuries per liter
613	Constituent was detected above the laboratory method detection limit.
<140	Constituent was not detected above the laboratory detection limit.
--	Constituent not analyzed.

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Table 12. Groundwater Analytical Results, PSEG Nuclear, LLC, Salem Generating Station, Hancock's Bridge, New Jersey.

Well Identification	Sample Date	Tritium (pCi/L)	Major Cations and Anions		Gamma-Emmitting Isotopes (pCi/L)				
			Boron (ug/L)	Sodium (mg/L)	Potassium-40	Radium-Natural	Thorium-232	Thorium-234	Uranium-235
AC	10/28/03	**10,900,000**	**253,000**	**30.8**	--	--	--	--	--
AC	11/03/03	**14,200,000**	**332,000**	**30.4**	--	--	--	--	--
AC	11/18/03	**14,200,000**	--	--	--	--	--	--	--
AC	12/18/03	**15,000,000**	--	--	--	--	--	--	--
AC	01/20/04	**10,700,000**	--	--	--	--	--	--	--
AD	10/27/03	**244,000**	--	--	--	--	--	--	--
AD	11/02/03	**242,000**	--	--	--	--	--	--	--
AD	11/17/03	**225,000**	--	--	--	--	--	--	--
AD	12/04/03	**392,000**	--	--	--	--	--	--	--
AD	12/16/03	**487,000**	--	--	--	--	--	--	--
AD	01/14/04	**220,000**	--	--	--	--	--	--	--
AE	10/27/03	**5,990**	--	--	--	--	--	--	--
AE	11/02/03	**5,710**	--	--	--	--	--	--	--
AE	11/19/03	**6,910**	234	14.2	--	--	--	--	--
AE	12/04/03	**6,310**	--	--	--	--	--	--	--
AE	12/18/03	**16,100**	--	--	--	--	--	--	--
AE	01/14/04	**12,600**	--	--	--	--	--	--	--
AF	10/07/03	<142	**380**	**227**	--	--	--	--	--
AF	10/27/03	**242**	--	--	--	--	--	--	--
AF	11/10/03	**330**	--	--	--	--	--	--	--
AF	11/19/03	**256**	--	--	--	--	--	--	--
AF	11/24/03	**245**	429	**545**	--	--	--	--	--
AF	12/10/03	**343**	--	--	--	--	--	--	--
AF	12/22/03	**302**	--	--	--	--	--	--	--

Notes:

mg/L	Milligrams per liter
pCi/L	Picocuries per liter
242	Constituent was detected above the laboratory method detection limit.
<142	Constituent was not detected above the laboratory detection limit.
--	Constituent not analyzed.

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D-01

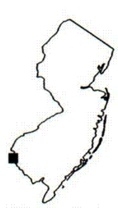
SCALE 1:24000

1 ½ 0 1 MILE

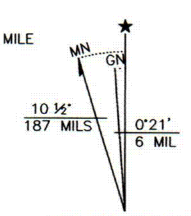
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 .5 0 1 KILOMETER

CONTOUR INTERVAL 10 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929



QUADRANGLE LOCATION



UTM GRID AND 1981 MAGNETIC NORTH

SOURCE: USGS 7.5 MIN. TOPOGRAPHICAL QUADRANGLE TAYLORS BRIDGE, DEL–N.J. 1948, PHOTOREVISED 1981.

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DRAWN M. WASILEWSKI	DATE 2/27/04	PROJECT MANAGER P. MILIONIS	DEPARTMENT MANAGER D. FULTON
STATION LOCATION		LEAD DESIGN PROF. S. POTTER	CHECKED B. PIERCE
PSEG NUCLEAR, LLC SALEM GENERATING STATION ARTIFICIAL ISLAND HANCOCK'S BRIDGE, NEW JERSEY		PROJECT NUMBER NP000571.0003	DRAWING NUMBER 1

G:\APROJECT\PSE&G\Salem\NP000571.0003 – Remedial Investigation\cadd\FIG–1 STATION LOCATION.DWG 3/18/2004 – 11:43:27 AM Layout: 8.5x11 H

C-01

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D-02

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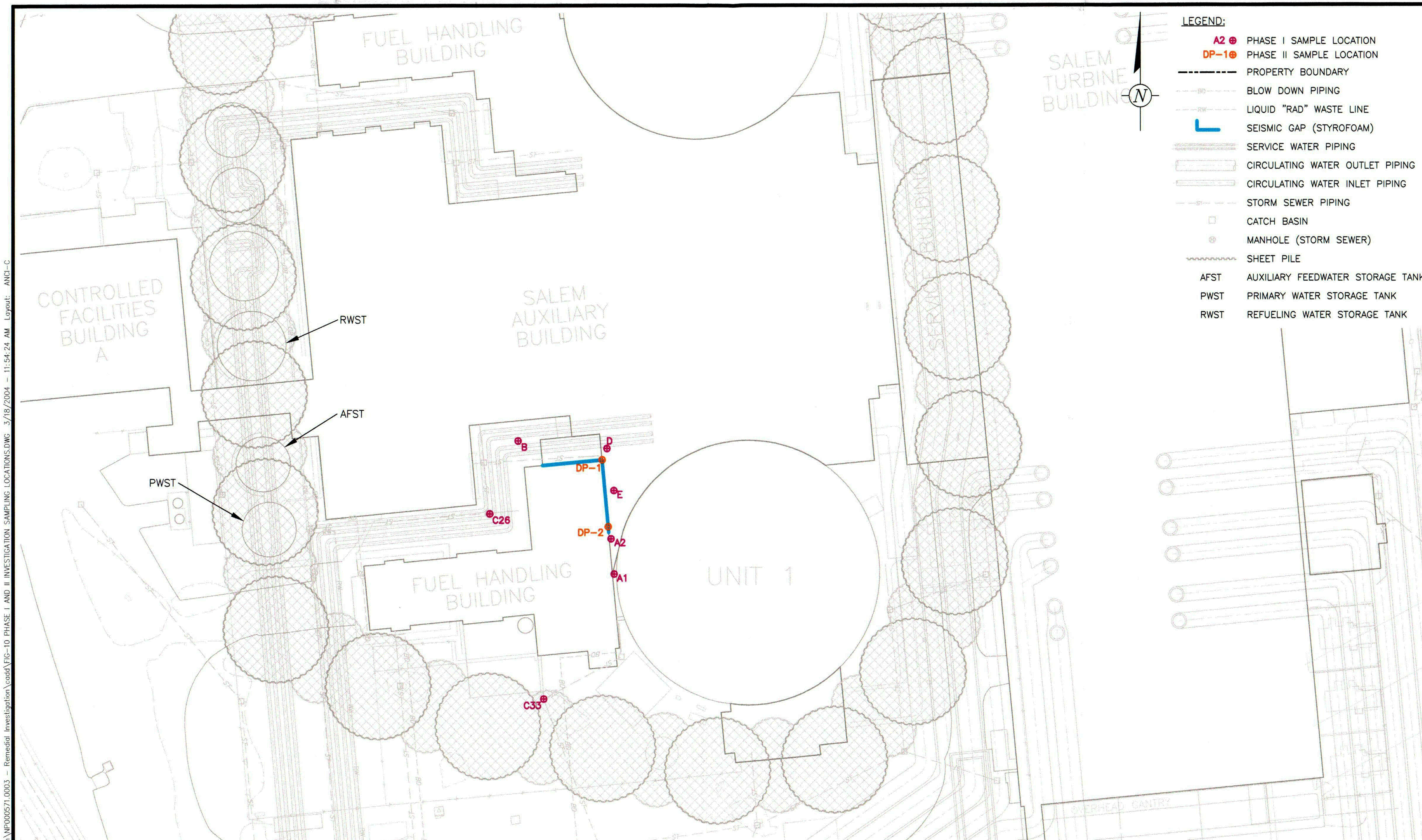
D-08



G:\APROJECT\PSE&G\Salem\NP000571.0003 – Remedial Investigation\cadd\FIG-10 PHASE I AND II INVESTIGATION SAMPLING LOCATIONS.DWG 3/18/2004 – 11:54:24 AM Layout: ANCI-C

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SCALE: 1"=50'

NO.	DATE	REVISION DESCRIPTION	BY / CKD

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6 Terry Drive
Suite 300, Newtown, Pa 18940
Tel: 267/685-1800 Fax: 267/685-1801

PSEG NUCLEAR, LLC
SALEM GENERATING STATION

ARTIFICIAL ISLAND
HANCOCK'S BRIDGE, NEW JERSEY

DRAWN M. WASILEWSKI	DATE 2/27/04	PROJECT MANAGER P. MILIONIS	DEPARTMENT MANAGER D. FULTON
PHASE I AND II INVESTIGATION SAMPLING LOCATIONS		LEAD DESIGN PROF. S. POTTER	CHECKED B. PIERCE
		PROJECT NUMBER NP000571.0003	DRAWING NUMBER 10

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D-10

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D-11

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"GROUNDWATER ELEVATION CONTOURS SHALLOW WATER-BEARING UNIT (FEBRUARY 20, 2004)"

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VINCENTOWN FORMATION
(HIGH - HIGH TIDE)"

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D-14

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D-15

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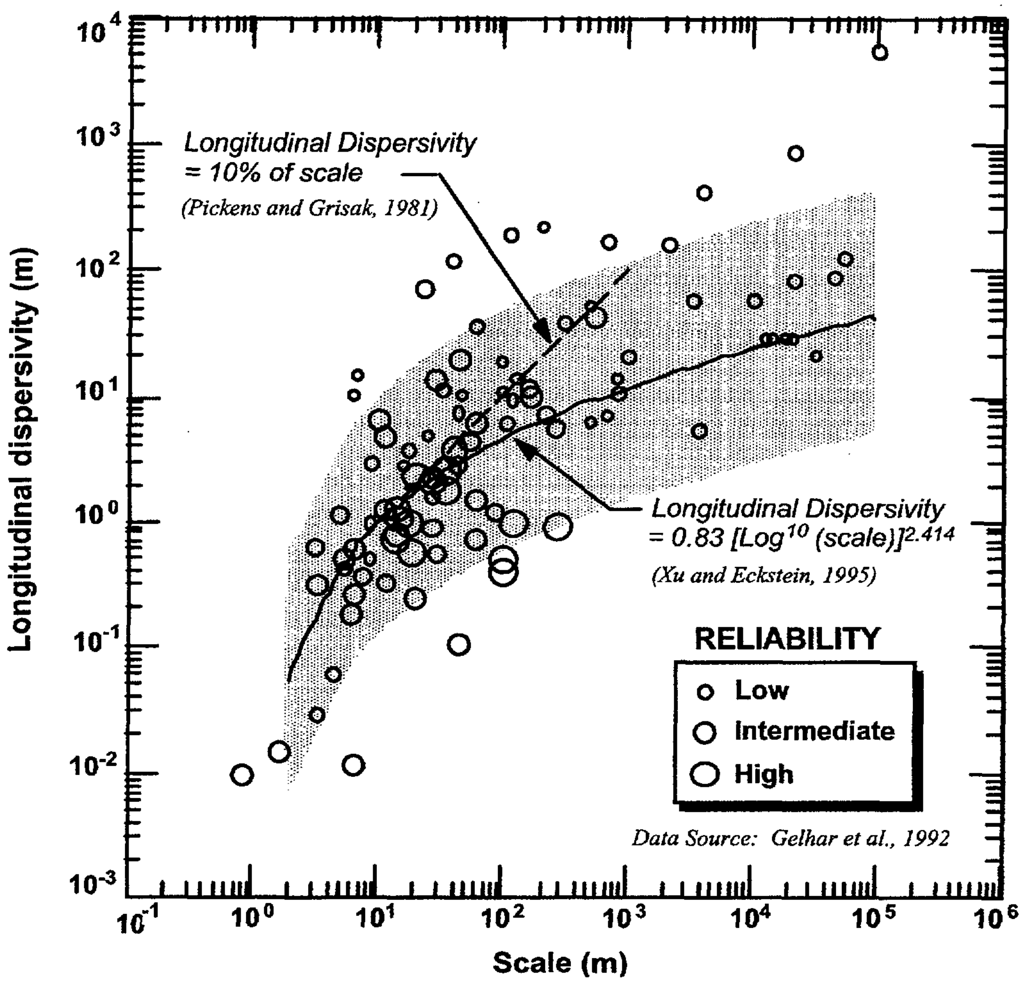

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Relationship Between Dispersivity and Travel Distance

PSEG Nuclear, LLC Salem Generating Station
Hancock's Bridge, New Jersey

FIGURE
19

DWG DATE: 3/04/04
PRJCT NO.: NP000571.0003
FILE NO.: Fig18.srf
CHECKED: B.Pierce
APPROVED: P.Milionis
DRAFTER: S.Potter