Remedial Action Work Plan

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

July 2004

PREPARED FOR

PSEG Services Corporation
80 Park Plaza
Newark, NJ 07102

ARCADIS

Part of a bigger picture

Environment, Health and Safety
P.O. Box 236, N33, Hancocks Bridge, NJ 08038-0236

PSEG
Services Corporation

CERTIFIED MAIL

June 15, 2004
PTS04011

Jill Lipoti, Ph.D.
Assistant Director
Radiation Protection and Release Prevention Element
New Jersey Department of Environmental Protection
Division of Environmental Safety and Health
PO Box 415
Trenton, NJ 08625-0415

REMEDIAL ACTION WORKPLAN, SALEM UNIT 1,
PSEG NUCLEAR, LLC, SALEM GENERATING STATION
LOWER ALLOWAY CREEK TOWNSHIP, SALEM COUNTY, NEW JERSEY

Dear Dr. Lipoti:

Enclosed please find three copies of Remedial Action Workplan (RAW) for tritium that has been detected in groundwater in the vicinity of Salem Unit 1. In accordance with New Jersey Department of Environmental Protection's (NJDEP) requirements, the RAW also provides the most current data generated by the on-going groundwater monitoring being conducted at Salem Unit 1.

The RAW proposes to remediate groundwater by using a "pump and treat" methodology. The remedial goal of the RAW is to achieve compliance with the NJDEP's groundwater standard as specified at NJAC7:26E-1.13(b) [referencing NJAC 7:9-6 Appendix: Table 1], for tritium of 20,000 pCi/L.

The pilot test has provided the necessary information to design a groundwater extraction system. The pilot test will be continued however, in order to collect additional information and data that will be used to identify the appropriate operational requirements for the groundwater extraction system and, if necessary, refine the design.

PSEG would like to implement the remedial actions as soon as is practical and therefore respectfully requests an expeditious review of the RAW. Your input to

this project is highly valued. We are available to meet with your staff regarding this RAW to discuss its content and answer any questions.

If you have any questions, please feel free to contact me at (856) 878-6920.

Sincerely,

Jeffrey J. Pantazes
Manager –
Permitting & Technical Services

Enclosures

CC Kent W. Tosch
Karen Tuccillo
Ron Nimitz

BC:		
	Lary Aldrich	S07
	Richard Blackman	T17
	John Carlin	N10
	Terry Cellmer	N33
	James Clancy	X14
	Frank Cook	N24
	James Eggers	N21(5 copies)
	Carl Fricker	S05
	David Garchow	N28
	Gregory Halnon	S05
	Edward Keating	N33
	Stanley LaBruna	T17A
	Steve Mannon	N24
	Christopher McAuliffe	T5C
	Allen Roberts	X06
	Steven Robitzski	X10
	John Ronafalvy	N33
	Timothy Taylor	N24
	File# Groundwater	

External

Steven Kaye, Ph.D. - SENES
David Kocher, Ph.D. – SENES
Peter Milionis – Arcadis
Brad Pierce – Arcadis
Robert Poreda, Ph.D. – University of Rochester
Scott Potter, Ph.D. - Arcadis

Environment, Health, and Safety
130 Money Island Road, Salem, NJ 08079

PSEG
Services Corporation

CERTIFIED MAIL

June 30, 2004
PTS04009

Dr. Jill Lipoti, Ph.D.
Assistant Director
Radiation Protection and Release Prevention Element
New Jersey Department of Environmental Protection
Division of Environmental Safety and Health
PO Box 415
Trenton, NJ 08625-0415

REMEDIAL INVESTIGATION REPORT AMENDMENT, SALEM UNIT 1,
PSEG NUCLEAR, LLC, SALEM GENERATING STATION
LOWER ALLOWAY CREEK TOWNSHIP, SALEM COUNTY, NEW JERSEY

Dear Dr. Lipoti:

Enclosed please find three copies of the Remedial Investigation Report (RIR) Amendment. The amendment is in response to NJDEP comments received in a letter dated June 10, 2004.

PSEG is preparing a Remedial Action Workplan (RAW) for submittal in July. The RAW will include an update on the data being generated by the on-going ground water monitoring program. Subsequent data updates to NJDEP are anticipated via the RAW periodic reports, after approval by the Department.

If you have any questions, please feel free to contact me at (856) 878-6920.

Sincerely,

John Ronafalvy for

Jeffrey J. Pantazes
Manager –
Permitting & Technical Services

Attachment

C: Kent W. Tosch
Karen Tuccillo
Ron Nimitz

Appendix K

Response to NJDEP Comments
dated June 10, 2004

Responses to NJDEP Comments dated June 10, 2004
Remedial Investigation Report – April 2004
PSEG Nuclear, LLC
Salem Generating Station
Hancock's Bridge, New Jersey

General Comments

1) **Uncertainties and Minimum Detectable Concentrations should be included when reporting radiological data.**

Analytical results of groundwater samples collected subsequent to those presented in the RIR through May 2004 are attached (Table 1). As requested, the analytical results for those analyses performed at Maplewood Testing Services will include both the uncertainties and minimum detectable concentrations for the analyses. Analyses performed at Salem Chemistry are not reported with uncertainties and minimum detectable concentrations. Analytical data presented in future submittals, such as Remedial Action Progress Reports, will include both uncertainties and Minimum Detectable Concentrations.

2) **The soil sample results you provided to my staff, independent of the RIR, should be included as a Table within the RIR.**

Analytical results of the soil samples collected during the installation of the monitoring wells at the Station are attached (Table 2).

Specific Comments

1) Section 2.2.1 - Historical Spills: **Documentation of historical leaks should be an appendix or should reference PSEG's Self-Assessment Report dated May 2003.**

In accordance with 10CFR50.75 (G), PSEG Nuclear, LLC maintains documentation of historical spills and releases that occur at the Station. PSEG Nuclear, LLC performed a review of this documentation to determine if any documented release or spill caused the elevated concentrations of tritium detected in the groundwater.. As stated in the Remedial Investigation Report, the documented releases or spills could not have resulted in the elevated levels of tritium detected in groundwater at the Station and are thus not appropriate for inclusion in the Remedial Investigation Report. The documentation reviewed by PSEG Nuclear, LLC is available and is periodically reviewed by the New Jersey Department of Environmental Protection Bureau of Nuclear Engineering (NJDEP-BNE) and the United States Nuclear Regulatory Commission (USNRC) during routine facility audits.

2) Section 5.2 - Phase II: **A description of the gross alpha analysis of the drinking water wells is provided, indicating that samples were taken from**

the facility water distribution system. Contrary to what is written, the DEP requested that PSE&G sample the individual wells, not the distribution system. Recently promulgated regulations by the US Environmental Protection Agency requires point of entry sampling. PSE&G must sample each production well point of entry. The gross alpha analyses must be done by a NJDEP Certified Laboratory and must be performed within 48 hours of sample collection. Please provide the laboratory results including uncertainties and minimum detectable concentrations.

PSEG collected the samples for gross alpha analysis from the point of entry into the drinking water system in accordance with 40 CFR 141.26; at the fresh water tanks. The fresh water tanks are the entry point into the potable water system, as well as other fresh water systems at the site. PSEG will collect additional samples at each Production Well that is normally operated to provide fresh water and submit the results of these analyses to the Department under separate cover.

3) <u>Section 6.5 - Monitoring Well Sampling and Analysis:</u> **The second bullet states that wells K, R, W, and F are consistently below level of detection. This is not the case, Please revise this statement.**

Comment Noted. The text in the referenced bullet should state that, "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 New Jersey Groundwater Quality Criteria for Tritium in Class II A aquifers (20,000 pCi/L)." Please remove and discard page 39 of the April 2004 RIR and replace it with the revised page 39, which is attached.

4) <u>Section 7.4 - Evaluation of the Kirkwood Formation:</u> **What is your resulting assessment of the conflicting geologic reports documented in this section? See specific comments from the New Jersey Geologic Survey (attached).**

As summarized in the New Jersey Geologic Survey (NJGS) correspondence attached to the June 10, 2004 comment letter, PSEG and the NJGS agree that the clay, confining-unit previously identified as Miocene-aged, Kirkwood Formation is not the Kirkwood Formation but something younger; however, the NJGS agreed that although the areal extent of the clay, confining unit may be limited to the east of the facility, the unit is continuous beneath the Station. Consequently, the clay, confining-unit will limit the migration of groundwater from the shallow, water-bearing unit to the deeper Vincentown Formation.

5) <u>Section 8.1 - Soil Samples:</u> **Results of all soil samples should be included in a Table within the RIR.**

As discussed in the response to General Comment 1, analytical results of the soil samples collected during the installation of the monitoring wells at the Station are summarized in the attached Table 2.

6) Section 8.2 - Groundwater Samples: **This report contends that the level of boron and Tc-99 are indicators that the water is from the Spent Fuel Pool. If one looks at the data from all the wells from the Shallow, Water Bearing Unit, both within and outside the limits of the cofferdam, one sees that only Well W, outside the limits of the cofferdam, has Tc-99 above background concentrations. Why don't the wells closest to the leak and within the limits of the cofferdam have Tc-99 concentrations above background? This should be explained. The only wells that have boron above background (for the wells that the analysis was performed) are Wells AC and S. Why isn't Boron found in more of the wells? Why is there boron in Wells AC and S, but no technicium-99? The discussion in Section 9.3 states that sorption is only a minor effect for boron. If stratification is the explanation, this discussion should be expanded. From the data presented, it seems these results are too inconsistent to prove that the leak is from the Spent Fuel Pool.**

Boron is both a tracer of Spent Fuel Pool water and a major ion in seawater. Boron concentrations greater than the concentration of boron in seawater (as is the case for Well AC and Well S), would demonstrate the presence of Spent Fuel Pool water. For other wells, there appears to be a background concentration of between 0.2 and 2 milligrams per liter (mg/L) of boron (for wells with no increase in tritium). If one uses the ratio of tritium to boron in the Spent Fuel Pool to calculate "a limit of detection" for boron, only waters with greater than 20,000 to 100,000 picocuries per liter (pCi/L) of tritium would have observable concentrations of boron above background. This analysis assumes simple mixing between Spent Fuel Pool water and ambient water. There is the distinct possibility that the Spent Fuel Pool "plume" exists as a thin stratified lens within the foundation soils. The tritium concentrations in the shallow wells may also be affected by diffusion of tritiated water into less tritiated groundwater above or below this lens. Because tritium diffuses faster than the borate ion, the ratio of tritium to boron will change throughout the plume (especially at the leading edge of the tritium diffusion front).

The behavior of technetium-99 (Tc-99) in soils may be highly dependent on the nature of the soils. Initial studies had suggested that Tc-99 moved at nearly the rate of groundwater, while other researchers had noted a significant retardation of Tc-99 on soils. Table 1 of the Remedial Investigation Report shows that the retardation factor for Tc-99 can range from 1 to 690, based on the soil density and composition. Our study indicates that Tc-99 has not migrated a significant distance away from the seismic gap and seems to support the latter research. Regardless, the tritium levels in Well AC (greater than 10,000,000 pCi/L) indicate there must be a release of primary water, and boron concentrations (greater than 100 mg/L) indicate it must be the Spent Fuel Pool. It was not foreseen in the initial phases of the investigation that levels of tritium of this magnitude would be detected thereby enabling clear indication of the source. Consequently, trace constituents were identified in the initial work plan to distinguish between low level sources. The Tc-99 results for Well W are anomalous and the boron and tritium results provide the

necessary information to identify the source.

Laboratory limitations have precluded analysis for Tc-99 in water with higher tritium concentrations. The Tc-99 analyses were performed by the University of Rochester, where procedures have been developed to measure extremely low levels of environmental metals, including Tc-99, using plasma source mass spectroscopy. The University of Rochester, however, cannot analyze samples with high tritium concentrations because the laboratory is designed and operated to perform extremely low level analyses. Samples with high concentrations of analytes can contaminate the laboratory environment, impacting the ability of the laboratory to perform low-level analyses. Samples containing high levels of tritium would require dilution to allow for analysis at the University of Rochester laboratory. Performing analysis for Tc-99 on water samples with high levels of tritium, such as those collected from wells with historically higher concentrations or from the seismic gap, would require dilutions of the sample up to three orders of magnitude to allow for analysis at the University of Rochester laboratory. This dilution factor would preclude the detection of Tc-99 at the concentrations detected at the site.

The TC-99 analysis was developed as one investigatory tool to identify the source of the tritiated groundwater. As concluded in the RIR, there is adequate evidence to conclude that the source of the tritiated groundwater is the spent fuel pool based on the other investigatory tools. The difficulties associated with detecting Tc-99 in samples requiring high dilution factors to meet the laboratory's limitations on tritium concentrations precludes pursuing this investigatory path.

7) <u>Section 8.2.1 - Summary of Analytical Data for Wells Screened in the Vincentown Formation:</u> **The discussion of Well K states that tritiated water traveled to the upper part of the Vincentown Formation 19 years ago (probably from another source). In the next paragraph, in the discussion of the results of Well L, PSE&G makes a general statement that there is not a major pathway for tritiated water into the Vincentown Formation. These two discussions contradict each other. Don't the results from Well K indicate that tritiated water can travel to the Vincentown Formation?**

The general statement should be clarified to state that there is not a major pathway of tritiated water through the clay, confining unit beneath the shallow, water bearing unit. If tritiated water had migrated from Salem Unit 1 to the Vincentown Formation, then elevated levels of tritium would be expected in groundwater samples collected from Well L and Well P located to the south and downgradient of Salem Unit 1. Instead, tritium concentrations indicated by groundwater samples collected from Well L and Well P are consistent with precipitation from 20 years ago (corrected for decay). Groundwater from the Vincentown Formation in the vicinity of Well K, which is located to the north and upgradient of Salem Unit 1, most likely recharged in the marshes 1 to 2 kilometers north and east of the Station. Hydraulic gradients for both the

shallow, water-bearing unit and the Vincentown Formation indicate that groundwater flow is from the north and east to the south and west. The source of the tritium in groundwater samples collected from Well K cannot be determined with absolute certainty. As indicated by data gathered from the other wells screened in the Vincentown Formation, the area of elevated tritium concentrations indicated by Well K has a minor areal extent with concentrations of tritium that are less than five percent of the New Jersey Groundwater Quality Criterion for Class II A aquifers (20,000 pCi/L).

8) **Section 8.2.2 - Summary of Analytical Data for Wells Screened in the Shallow, Water Bearing Unit - Within the Limits of the Cofferdam: How does PSE&G explain the absence of Tc-99 in all the wells within the limits of the cofferdam, when Well W, outside the limits of the cofferdam, appears to have a Tc-99 concentration 8 times background concentrations (based on the data presented without the uncertainties included).**

Please refer to the response to comment 6 regarding Section 8.2.

9) **Section 8.2.3 - Summary of Analytical Data for Wells Screened in the Shallow, Water Bearing Unit Outside the Limits of the Cofferdam: The discussion on Well W states that the Tc-99 concentrations is "slightly above" background, yet Appendix H states clearly that the concentration is above regional background levels. Please reconcile these two statements.**

The text in the report has been revised by deleting the word "slightly", to be consistent with Appendix H. Please remove and discard page 60 of the April 2004 RIR and replace it with the revised page 60, which is attached.

10) **Section 8.2.3 - Summary of Analytical Data for Wells Screened in the Shallow, Water Bearing Unit Outside the Limits of the Cofferdam (Appendix H): How far is Well W from the center of the plume? Need to complete this statement.**

Well W is located approximately 250 feet from the center of the plume. Please remove and this page from Appendix H in the April 2004 RIR and replace it with the revised page, which is attached.

11) **Section 8.2.3 - Summary of Analytical Data for Wells Screened in the Shallow, Water Bearing Unit Outside the Limits of the Cofferdam: The reason for why there was no boron analysis performed for Well AB and AD is that the tritium concentrations were too high (220,000 to 487,000 pCi/L). However, a boron analysis was performed for well AC with a much higher concentration of 15,000,000 pCi/L. Is this a valid reason or not?**

Groundwater samples collected to date from Well AB and Well AD were not

submitted to Maplewood Testing Services for boron or sodium analysis due to elevated tritium concentrations and the sample shipment restrictions associated with these tritium concentrations. Salem Chemistry has developed the capability to perform sodium and boron analyses on samples that cannot be transported to Maplewood Testing Services due to the tritium concentrations. The updated data report attached, as well as the June 7, 2004 routine data submittal, presents the results of the sodium and boron analyses on Wells AB and AD.

12) Section 9.3 - Sorptive Processes: **The paragraph under equation (5) states that "Solutes dissolved in the low pH water in soils without fine materials will tend to adsorb to soils and have K_d in the lower reported range". Shouldn't it be in the higher reported range?**

Comment noted. The text in the referenced paragraph should state "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 not 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 to adsorb to soils and have K_d in the higher reported range." Please remove and discard page 68 of the April 2004 RIR and replace it with the revised page 68, which is attached.

13) Section 9.6 - Tritium Age Dating and Travel Time: **An obvious conclusion for this section is to predict how long it will take for the tritiated water to reach the Vincentown Formation and what the concentration will be when it gets there. The estimated age of the plume (4.7 - 9 years) and the vertical travel time of 6-8 feet per year seems to put the plume at the right depth (around - 23 to -35 feet).**

The determination of recharge rate and vertical velocity for the plume only pertains to those wells within the shallow, water-bearing unit, which extends from ground surface to the clay confining-unit (between 35 and 50 feet below ground surface). The clay confining-unit, which is approximately 15 feet in thickness in the vicinity of Well K, will limit the vertical transport of groundwater. Although the age of the groundwater in the Vincentown Formation (15 to 20 years) suggests a similar recharge rate, the pathway from the shallow, water-bearing unit to the Vincentown Formation does not originate in the area of Salem Unit 1. Both hydrogeologic and geochemical data suggest that water in the Vincentown Formation near the Station recharges in the vicinity of the marshes to the north and east of the Station. Relative to the shallow, water-bearing unit, the Vincentown Formation has a higher hydraulic conductivity. Water recharging from the marshes to the Vincentown Formation migrated to the area beneath the Station in about 20 years (4 vertical feet per year and 50 –100 horizontal feet per year).

14) Section 10.0 - Health and Environmental Risk Assessment: **The last**

sentence of the first paragraph should reference Section 10.3, not 6.3.

Comment noted. The last sentence of the first paragraph should reference Section 10.3 and not Section 6.3. Please remove and discard page 70 of the April 2004 RIR and replace it with the revised page 70, which is attached.

15) <u>Section 11.1 - Conclusions:</u> **The numbered list is supposed to support the evidence that the source of tritium detected in groundwater was the Spent Fuel Pool. Number 2 seems to support the conclusion that the tritiated water is NOT from the Spent Fuel Pool. In fact there is not strong evidence other than Number 1, presented to support that claim. Number 4 ignores the data from Well K where tritiated water did travel to the Vincentown Formation. From the analysis in Section 9, It appears that the plume from the Spent Fuel Pool is not in the Vincentown Formation because it hasn't had time to travel there yet.**

As stated in previous responses, if groundwater flowed directly from Salem Unit 1 to the Vincentown Formation, then Wells L and P should have high tritium. Well K has minor tritium concentrations (less than 5% of the New Jersey Groundwater Quality Criterion) that could have come from any one of a number of sources, both anthropogenic and natural. Again, water does not flow vertically from the surface to the Vincentown in the vicinity of Salem 1. There is a large zone of low conductivity sediments that separate the two water bearing zones and water cannot flow from regions of lower hydraulic head to regions of higher hydraulic head (i.e., upgradient).

16) <u>Table 6:</u> **The data from Wells AJ, AL, AG-S/D and AH-S/D should be reported in the RIR. The remedial investigation cannot be considered complete until the data from these wells are reported.**

As stated in the response to General Comment 1, analytical results of groundwater samples collected subsequent to those presented in the RIR through May 2004 are attached. Groundwater samples will continue to be collected as the project enters into the Remedial Action Work Plan and Remedial Action phases. Analytical results of these groundwater samples will be periodically summarized and submitted to NJDEP in Progress Reports. The continued collection and analysis of groundwater samples will be performed to evaluate/monitor the performance of the remediation.

Revised Pages for Revised Remedial Investigation Report

Instructions:

Table of Contents	Replace Table of Contents in its entirety
Page 39	Replace Page 39 of the Remedial Investigation Report
Page 60	Replace Page 60 of the Remedial Investigation Report
Appendix H – Page 5	Replace Page 5 of Appendix H
Page 68	Replace Page 68 of the Remedial Investigation Report
Page 70	Replace Page 70 of the Remedial Investigation Report

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above and downgradient of the circulation water discharge pipes. The well was constructed with two-inch diameter Schedule 40 PVC casing and well screens (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 New Jersey Groundwater Quality Criteria for Tritium in Class II A aquifers (20,000 pCi/L).;

- 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,

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, above the expected background value.

3.0 Summary for the Shallow, Water-Bearing Formation Outside of the Limits of the Cofferdam.

- Well S – The groundwater age determination of the sample from Well S indicates a relatively young age (less than one year). The recent age of this water is consistent with other shallow wells close to the plant and inside of the cofferdam. The Tc-99 concentration for this well is at or near the regional background concentration of 0.5 pCi/L.

- Well T – Analytical results of the low-level tritium analysis of the sample from Well T indicate a tritium concentration of 257 pCi/L. The groundwater age analysis for this sample indicates an age of approximately 1.6 years, which is consistent with the ages of other samples collected from this zone. The analytical results of the groundwater sample collected from Well T indicate a methane concentration and low concentrations of dissolved atmospheric gases (15% of solubility) consistent with recharge in the marshes to the east of the Station (similar to Wells Q and U). The Tc-99 concentration for the sample from Well T is at regional background concentration.

- Well U – Analytical results of the low-level tritium analysis of the sample from Well U indicate a tritium concentration of 78 pCi/L. The groundwater age analysis for this sample indicates an age of approximately 4.1 years, which is consistent with the ages of other groundwater samples collected from monitoring wells screened in this zone. The analytical results of the groundwater sample collected from Well U indicate a methane concentration and low concentrations of dissolved atmospheric gases (15% of solubility) consistent with recharge in the marshes to the east of the Station (similar to Well T). The Tc-99 concentration for the sample from Well T is at regional background concentration.

- Well W –Analytical results of the groundwater sample collected from Monitoring Well W indicate a tritium concentration of 11,300 pCi/L, and the groundwater age determination for this well indicates an age of four years. The analytical results for the groundwater sample from Well W also indicate an elevated concentration of dissolved methane, which suggests that groundwater at Well W is a mixture of groundwater with characteristics similar to groundwater from Well T (or Well Z) with tritiated water from plant activity. Well W is located at or near the boundary between methane-rich water flowing from east to the south and west, and tritiated, methane free water that recharges to the south of Salem Unit #1. The Tc-99 concentration for the sample from Well W is approximately 4 pCi/L, which is above the regional background concentration (0.5 pCi/L). The ratio of tritium to Tc-99 (2700) is very close to the ratio in the Spent Fuel Pool (Tc-99 data from Ginna which has similar tritium and Spent Fuel Pool characteristics to Salem). Although Well W is located 250 feet from the center of the plume, it is only a few meters outside of the cofferdam.

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

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 not 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 to adsorb to soils and have K_d in the higher 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:

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

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:

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

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 10.3, 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

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Boring Identification	Sample Date	Sample Type	Sample Depth (feet bgs)[3]	Plant-Related Gamma-Emitting Isotopes (uCi/g)	Non Plant-Related Gamma-Emitting Isotopes (uCi/g)								
					K-40	Tl-208	Bi-212	Pb-212	Bi-214	Pb-214	Ra-226	Ac-228	Th-234
Well S	05/29/03	Discrete[1]	9.5 - 11.5	--	2.40E-06	4.80E-08	5.90E-07	--	2.20E-07	1.50E-07	8.70E-07	3.70E-07	1.10E-06
Well S	05/29/03	Discrete[1]	14 - 16	--	2.90E-06	6.30E-08	--	1.50E-07	2.30E-07	1.40E-07	--	--	--
Well S	05/29/03	Discrete[1]	19 - 21	--	4.90E-06	--	--	3.40E-07	--	4.20E-07	--	--	--
Well S	05/29/03	Discrete[1]	24 - 26	--	9.30E-06	1.50E-07	8.90E-07	5.00E-07	3.90E-07	3.30E-07	9.20E-07	7.10E-07	2.40E-06
Well S	05/29/03	Discrete[1]	29 - 31	--	1.10E-05	2.60E-07	9.10E-07	--	4.30E-07	4.00E-07	--	5.20E-07	1.90E-06
Well S	05/29/03	Discrete[1]	34 - 36	--	8.70E-06	2.60E-07	1.40E-06	6.30E-07	6.40E-07	7.00E-07	--	8.70E-07	2.50E-06
Well T	06/06/03	Discrete[1]	9 - 11	--	9.50E-06	2.40E-07	9.50E-07	8.00E-07	3.80E-07	4.10E-07	--	--	--
Well T	06/06/03	Discrete[1]	14.5 - 16.5	--	9.00E-06	1.90E-07	--	5.60E-07	2.60E-07	3.40E-07	--	--	--
Well T	06/06/03	Discrete[1]	19.5 - 21.5	--	9.50E-06	1.70E-07	9.20E-07	5.40E-07	3.70E-07	4.50E-07	--	--	--
Well T	06/06/03	Discrete[1]	24.5 - 26.5	--	1.60E-05	3.40E-07	1.70E-06	--	2.80E-07	--	--	1.10E-06	--
Well T	06/06/03	Discrete[1]	29.5 - 31.5	--	1.60E-05	3.20E-07	1.70E-06	9.10E-07	6.80E-07	3.80E-07	--	9.20E-07	--
Well T	06/06/03	Discrete[1]	31.5 - 33.5	--	5.7E--06	3.30E-07	--	1.10E-06	7.20E-07	6.90E-07	1.80E-06	9.60E-07	2.70E-06
Well T	07/18/03	Composite[2]	Drum 1 (A)	--	--	--	--	--	1.30E-07	1.10E-07	--	--	--
Well T	07/18/03	Composite[2]	Drum 2 (A)	--	--	--	--	--	--	--	--	--	--
Well T	07/18/03	Composite[2]	Drum 3 (A)	Cs-137, 8.3E-08	--	--	--	--	--	--	--	--	--
Well T	07/18/03	Composite[2]	Drum 4 (A)	--	--	--	--	--	--	--	--	--	--
Well T	07/18/03	Composite[2]	Drum 5 (A)	--	--	--	--	--	--	--	--	--	--
Well T	07/18/03	Composite[2]	Drum 6 (A)	--	--	--	--	--	--	2.50E-07	--	--	--
Well T	07/18/03	Composite[2]	Drum 7 (A)	--	--	--	--	--	--	--	--	--	--
Well T	07/18/03	Composite[2]	Drum 8 (A)	--	--	--	--	--	1.50E-07	1.30E-07	--	--	--
Well T	07/18/03	Composite[2]	Drum 9 (A)	--	--	--	--	--	--	--	--	--	--

Notes:

-- Analytical parameter was not detected above the laboratory lower limit of detection.

feet bgs Feet below ground surface.

1 Discrete samples were obtained from split-spoons collected during the advancement of the borings.

2 Composite samples were obtained from drill cuttings from the boring, which were containerized in 55-gallon steel drums.

[3] For discrete samples, the sample depth is presented in feet below ground surface. For composite samples, because they were obtained from drums the sample depth is unkown. The information provided is the drum identification number and the composite sample identification. Drum identification numbers are from shallowest (1) to deepest (2 through 6).

Table 02. Soil Analytical Results, PSEG Nuclear, LLC, Salem Generating Station, Hancock's Bridge, New Jersey.

Boring Identification	Sample Date	Sample Type	Sample Depth (feet bgs)[3]	Plant-Related Gamma-Emitting Isotopes (uCi/g)	Non Plant-Related Gamma-Emitting Isotopes (uCi/g)								
					K-40	Tl-208	Bi-212	Pb-212	Bi-214	Pb-214	Ra-226	Ac-228	Th-234
Well V	05/28/03	Discrete[1]	9 - 11	--	9.35E-06	1.40E-07	8.00E-07	4.10E-77	2.20E-07	3.90E-07	1.30E-06	5.10E-07	1.60E-06
Well V	05/28/03	Discrete[1]	14 - 16	--	9.70E-06	8.90E-08	--	2.90E-07	2.50E-07	2.80E-07	1.30E-06	4.60E-07	1.30E-06
Well V	05/28/03	Discrete[1]	18 - 20	--	1.60E-05	--	--	--	--	--	--	--	--
Well V	05/28/03	Discrete[1]	19 - 21	--	9.60E-06	1.9E--07	--	4.20E-07	2.60E-07	4.60E-07	--	6.70E-07	1.30E-06
Well V	05/28/03	Discrete[1]	24 - 26	--	9.30E-06	2.10E-07	--	--	2.30E-07	3.00E-07	8.50E-07	6.6EE-07	--
Well V	05/28/03	Discrete[1]	28 - 30	--	9.40E-06	1.70E-07	--	--	3.20E-07	3.10E-07	1.00E-06	6.30E-07	1.70E-06
Well V	05/28/03	Discrete[1]	31 - 33	--	1.60E-05	3.50E-07	--	1.00E-06	5.40E-07	5.40E-07	1.70E-06	1.00E-06	--
Well V	05/28/03	Discrete[1]	34 - 36	--	1.60E-05	2.90E-07	--	1.30E-06	1.00E-06	1.10E-06	3.20E-06	1.10E-06	--
Well V	06/09/03	Discrete[1]	48 - 50	--	1.10E-05	2.90E-07	--	8.00E-07	1.00E-06	8.10E-07	--	1.00E-06	3.30E-06
Well W	06/03/03	Discrete[1]	9.5 - 11	--	4.29E-06	9.60E-08	--	3.10E-07	2.60E-07	4.30E-07	--	3.80E-07	--
Well W	06/03/03	Discrete[1]	18 - 20	--	1.20E-05	3.20E-07	--	1.20E-06	6.80E-07	5.10E-07	--	1.20E-06	--
Well W	06/03/03	Discrete[1]	24 - 26	--	1.40E-05	3.20E-07	2.00E-06	--	7.20E-07	4.90E-07	1.80E-06	1.10E-06	2.20E-06
Well W	06/03/03	Discrete[1]	29 - 31	--	1.50E-05	3.40E-07	--	1.10E-06	5.70E-07	6.30E-07	2.1E--06	1.40E-06	2.70E-06
Well W	06/03/03	Discrete[1]	34 - 36	--	1.50E-05	2.80E-07	1.50E-06	--	5.90E-07	6.70E-07	2.30E-06	9.10E-07	2.20E-06
Well Y	10/06/03	Composite[2]	Drum 1 (A)	--	8.50E-06	2.30E-07	--	--	8.10E-07	6.60E-07	--	--	--
Well Y	10/06/03	Composite[2]	Drum 1 (B)	--	7.30E-06	3.20E-07	--	--	3.80E-07	3.50E-07	--	--	--
Well Y	10/07/03	Composite[2]	Drum 2 (A)	--	--	--	--	--	--	--	--	--	--
Well Y	10/07/03	Composite[2]	Drum 2 (B)	--	--	--	--	--	--	--	--	--	--
Well Z	10/06/03	Composite[2]	Drum 1 (A)	--	6.00E-06	1.80E-07	--	6.00E-07	5.40E-07	4.30E-07	--	--	--
Well Z	10/06/03	Composite[2]	Drum 1 (B)	--	6.00E-06	2.50E-07	--	5.90E-07	--	3.40E-07	--	--	--
Well Z	10/07/03	Composite[2]	Drum 2 (A)	--	--	--	--	--	--	--	--	--	--
Well Z	10/07/03	Composite[2]	Drum 2 (B)	--	--	--	--	--	--	--	--	--	--

Notes:

-- Analytical parameter was not detected above the laboratory lower limit of detection.

feet bgs Feet below ground surface.

1 Discrete samples were obtained from split-spoons collected during the advancement of the boring.

2 Composite samples are drill cuttings from the boring, which were containerized in 55-gallon steel drums.

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					K-40	Tl-208	Bi-212	Pb-212	Bi-214	Pb-214	Ra-226	Ac-228	Th-234
Well AA	10/06/03	Composite[2]	Drum 1 (A)	--	--	--	--	--	--	2.90E-07	3.20E-06	--	--
Well AA	10/06/03	Composite[2]	Drum 1 (B)	--	--	--	--	--	2.20E-07	4.90E-07	--	--	--
Well AA	10/08/03	Composite[2]	Drum 2 (A)	--	--	--	--	--	--	--	--	--	--
Well AA	10/08/03	Composite[2]	Drum 2 (B)	--	--	--	--	--	--	--	--	--	--
Well AB	10/06/03	Composite[2]	Drum 1 (A)	--	--	--	--	--	--	--	--	--	--
Well AB	10/06/03	Composite[2]	Drum 1 (B)	--	1.90E-06	1.20E-07	--	3.00E-07	2.10E-07	--	--	--	--
Well AB	10/06/03	Composite[2]	Drum 3 (A)	--	--	1.20E-07	--	--	--	2.70E-07	--	--	--
Well AB	10/06/03	Composite[2]	Drum 3 (B)	--	--	--	--	--	2.70E-07	--	--	--	--
Well AB	10/08/03	Composite[2]	Drum 4 (A)	--	--	--	--	--	--	--	--	--	--
Well AB	10/08/03	Composite[2]	Drum 4 (B)	--	--	--	--	--	--	--	--	--	--
Well AC	10/06/03	Composite[2]	Drum 1 (A)	--	--	--	--	--	--	--	--	--	--
Well AC	10/06/03	Composite[2]	Drum 1 (B)	--	--	--	--	4.00E-07	--	--	--	--	--
Well AC	10/08/03	Composite[2]	Drum 2 (A)	--	--	--	--	--	--	--	--	--	--
Well AC	10/08/03	Composite[2]	Drum 2 (B)	--	--	--	--	--	--	--	--	--	--

Notes:

-- Analytical parameter was not detected above the laboratory lower limit of detection.

feet bgs Feet below ground surface.

1 Discrete samples were obtained from split-spoons collected during the advancement of the boring.

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Boring Identification	Sample Date	Sample Type	Sample Depth (feet bgs)[3]	Plant-Related Gamma-Emitting Isotopes (uCi/g)	Non Plant-Related Gamma-Emitting Isotopes (uCi/g)								
					K-40	Tl-208	Bi-212	Pb-212	Bi-214	Pb-214	Ra-226	Ac-228	Th-234
Well AD	10/06/03	Composite[2]	Drum 1 (A)	--	--	--	--	--	--	--	--	--	--
Well AD	10/06/03	Composite[2]	Drum 1 (B)	--	--	--	--	--	--	--	--	--	--
Well AD	10/06/03	Composite[2]	Drum 2 (A)	--	--	--	--	--	--	--	--	--	--
Well AD	10/06/03	Composite[2]	Drum 2 (B)	--	--	--	--	--	--	--	--	--	--
Well AD	10/06/03	Composite[2]	Drum 3 (A)	--	9.30E-06	1.90E-07	--	7.50E-07	--	3.60E-07	1.90E-06	--	--
Well AD	10/06/03	Composite[2]	Drum 3 (B)	--	3.20E-06	--	2.90E-06	5.90E-07	4.60E-07	4.80E-07	--	8.10E-07	3.90E-06
Well AD	10/06/03	Composite[2]	Drum 4 (A)	--	9.50E-06	2.20E-07	--	5.10E-07	--	5.60E-07	--	--	--
Well AD	10/06/03	Composite[2]	Drum 4 (B)	--	9.20E-06	1.80E-07	1.50E-06	5.00E-07	4.60E-09	6.90E-07	--	6.50E-07	--
Well AD	10/06/03	Composite[2]	Drum 5 (A)	--	7.20E-06	1.60E-07	2.00E-06	4.50E-07	--	8.60E-07	--	--	4.50E-06
Well AD	10/06/03	Composite[2]	Drum 5 (B)	--	7.90E-06	2.20E-07	--	7.50E-07	6.60E-07	6.10E-07	--	--	--
Well AD	10/06/03	Composite[2]	Drum 6 (A)	--	5.90E-06	1.90E-07	--	2.90E-07	7.80E-07	3.90E-07	--	--	--
Well AD	10/06/03	Composite[2]	Drum 6 (B)	--	1.00E-05	--	--	4.00E-07	8.20E-07	8.20E-07	--	--	3.40E-06
Well AE	10/08/03	Composite[2]	Drum 1 (A)	--	--	--	--	--	--	--	--	--	--
Well AE	10/08/03	Composite[2]	Drum 1 (B)	--	--	--	--	2.50E-07	2.40E-07	--	--	--	--
Well AF	10/06/03	Composite[2]	Drum 1 (A)	--	5.90E-06	1.80E-07	--	6.10E-07	6.70E-07	4.80E-07	--	--	--
Well AF	10/06/03	Composite[2]	Drum 1 (B)	--	5.40E-06	--	--	2.90E-07	3.50E-07	5.80E-07	--	7.50E-07	--
Well AF	10/06/03	Composite[2]	Drum 2 (A)	--	2.20E-06	--	--	2.90E-07	--	5.30E-07	--	--	--
Well AF	10/06/03	Composite[2]	Drum 2 (B)	--	--	--	--	--	--	4.10E-07	--	--	--
Well AF	10/08/03	Composite[2]	Drum 3 (A)	--	--	--	--	--	--	2.30E-07	--	--	--
Well AF	10/08/03	Composite[2]	Drum 3 (B)	--	--	--	--	--	--	--	--	--	--

Notes:

-- Analytical parameter was not detected above the laboratory lower limit of detection.

feet bgs Feet below ground surface.

1 Discrete samples were obtained from split-spoons collected during the advancement of the boring.

2 Composite samples are drill cuttings from the boring, which were containerized in 55-gallon steel drums.

3 For discrete samples, the sample depth is presented in feet below ground surface. For composite samples, because they were obtained from drums

the sample depth is unkown. The information provided is the drum identification number and the composite sample identification. Drum identification numbers were listed from shallowest (1) to deepest (2 through 6).

Table 01. Recent Groundwater Analytical Results, PSEG Nuclear, LLC, Salem Generating Station, Hancock's Bridge, New Jersey.

Well Identification	Sample Date	Tritium			Major Cations and Anions	
		Result (pCi/L)	Deviation (pCi/L)	LLD (pCi/L)	Boron (ug/L)	Sodium (mg/L)
K	02/04/04	762	94.6	139	--	--
L	05/04/04	<138	82.1	138	--	--
L	05/10/04	<138	83.9	138	--	--
L[1]	05/19/04	<5,780	NA	NA	--	--
L[1]	05/24/04	<4,560	NA	NA	--	--
M	01/22/04	7,340	164	140	--	--
M[2]	02/17/04	11,300	NA	NA	--	--
M	03/05/04	7,170	168	146	150	22
M	04/29/04	6,510	159	141	120	21
M	05/11/04	2,350	117	141	--	--
N	02/11/04	5,950	154	139	--	--
N	03/18/04	6,550	162	145	--	--
N	04/08/04	7,180	164	137	230	17
N[2]	05/12/04	10,200	NA	NA	<3,330	19.4
N[2]	06/03/04	9,760	NA	NA	--	--
O	01/14/04	3,750	132	141	300	1,850
O[2]	02/09/04	24,200	NA	NA	--	--
O[2]	03/03/04	21,800	NA	NA	283	1,720
O[2]	03/23/04	21,000	NA	NA	--	--
O	04/06/04	19,300	247	136	281	120.0
O	05/03/04	20,400	253	140	--	--
O	05/11/04	20,700	254	140	--	--

Notes:

ug/L	Micrograms per liter
mg/L	Milligrams per liter
pCi/L	Picocuries per liter
1	Reported analytical results are from Salem Chemistry. Analytical results from Maplewood are pending.
2	Reported analytical results are from Salem Chemistry. Groundwater samples were not submitted to Maplewood for additional analysis.
<138	Constituent was not detected above the laboratory detection limit.
762	Constituent was detected above the laboratory method detection limit.

NA Not Available - Deviation and LLD for Salem Chemistry are not reported.
-- Constituent not analyzed.

Table 01. Recent Groundwater Analytical Results, PSEG Nuclear, LLC, Salem Generating Station, Hancock's Bridge, New Jersey.

Well Identification	Sample Date	Tritium			Major Cations and Anions	
		Result (pCi/L)	Deviation (pCi/L)	LLD (pCi/L)	Boron (ug/L)	Sodium (mg/L)
P	01/22/04	<144	85.5	144	--	--
P	04/28/04	<139	83.2	139	441	1,550
Q	01/08/04	<142	83.1	142	300	1,850
Q	02/04/04	<139	83.5	139	--	--
Q	03/22/04	<144	85.4	144	283	1,720
Q[1]	06/04/04	<4,560	NA	NA	--	--
R	01/22/04	2,210	116	143	--	--
R	02/09/04	2,230	115	140	--	--
R	03/05/04	2,200	117	146	--	--
R[2]	04/28/04	<5,780	NA	NA	265	41.6
R[2]	05/24/04	4,800	NA	NA	--	--
S[2]	01/20/04	1,420,000	NA	NA	--	--
S[2]	02/17/04	1,250,000	NA	NA	--	--
S[2]	03/18/04	1,220,000	NA	NA	--	--
S[2]	04/06/04	1,160,000	NA	NA	--	--
S[2]	05/04/04	1,100,000	NA	NA	44,500	34.6
S[2]	05/19/04	889,000	NA	NA	--	--
T	03/22/04	<142	84.0	142	649	986
T	04/12/04	<141	84.1	141	762	920
U	03/22/04	<144	87.5	144	379	168
U	04/12/04	182	84.2	136	392	146

Notes:

ug/L	Micrograms per liter
mg/L	Milligrams per liter
pCi/L	Picocuries per liter
1	Reported analytical results are from Salem Chemistry. Analytical results from Maplewood are pending.
2	Reported analytical results are from Salem Chemistry. Groundwater samples were not submitted to Maplewood for additional analysis.
<144	Constituent was not detected above the laboratory detection limit.
182	Constituent was detected above the laboratory method detection limit.

1,250,000	Constituent was detected above its New Jersey Groundwater Quality Criteria.
NA	Not Available - Deviation and LLD for Salem Chemistry are not reported.
--	Constituent not analyzed.

Table 01. Recent Groundwater Analytical Results, PSEG Nuclear, LLC, Salem Generating Station, Hancock's Bridge, New Jersey.

Well Identification	Sample Date	Tritium			Major Cations and Anions	
		Result (pCi/L)	Deviation (pCi/L)	LLD (pCi/L)	Boron (ug/L)	Sodium (mg/L)
V	03/22/04	290	90.2	144	456	556
V	04/12/04	316	86.9	137	529	567
W	01/14/04	17,100	232	144	--	--
W	02/02/04	19,600	251	144	--	--
W	03/03/04	5,320	151	146	280	273
W	04/29/04	4,570	140	140	140	212
W	05/10/04	2,350	117	141	--	--
W[1]	05/24/04	6,610	NA	NA	--	--
Y	01/06/04	<142	84.7	142	--	--
Y	02/02/04	<145	86.5	145	--	--
Y	03/23/04	<145	86.0	145	--	--
Y	04/07/04	<136	81.9	136	830	1,080
Y	05/10/04	<143	84.7	143	--	--
Z	01/06/04	648	94.5	142	--	--
Z	02/02/04	538	94.7	145	--	--
Z	03/23/04	412	92.1	144	--	--
Z	04/07/04	580	91.2	137	500	531
Z	05/10/04	561	93.3	142	--	--
AA	01/06/04	713	95.1	141	--	--
AA	02/09/04	1,130	99.9	139	--	--
AA	03/18/04	2,610	120	140	--	--
AA	04/12/04	3,140	126	140	240	169
AA[1]	05/03/04	<5,590	NA	NA	--	--
AA[1]	05/19/04	<3,320	NA	NA	<3,330	168

Notes:

ug/L	Micrograms per liter
mg/L	Milligrams per liter
pCi/L	Picocuries per liter
1	Reported analytical results are from Salem Chemistry. Analytical results from Maplewood are pending.
<142	Constituent was not detected above the laboratory detection limit.
561	Constituent was detected above the laboratory method detection limit.
NA	Not Available - Deviation and LLD for Salem Chemistry are not reported.

-- Constituent not analyzed.

Table 01. Recent Groundwater Analytical Results, PSEG Nuclear, LLC, Salem Generating Station, Hancock's Bridge, New Jersey.

Well Identification	Sample Date	Tritium			Major Cations and Anions	
		Result (pCi/L)	Deviation (pCi/L)	LLD (pCi/L)	Boron (ug/L)	Sodium (mg/L)
AB[2]	01/14/04	281,000	NA	NA	--	--
AB[2]	02/17/04	215,000	NA	NA	--	--
AB[2]	03/03/04	193,000	NA	NA	--	--
AB[2]	04/06/04	260,000	NA	NA	--	--
AB[2]	05/04/04	136,000	NA	NA	9,300	134
AB[2]	05/11/04	144,000	NA	NA	--	--
AB[2]	05/19/04	172,000	NA	NA	<3,330	292
AB[2]	05/24/04	213,000	NA	NA	--	--
AB[2]	06/03/04	210,000	NA	NA	<3,330	105
AC[2]	01/20/04	10,700,000	NA	NA	--	--
AC[2]	02/18/04	9,170,000	NA	NA	--	--
AC[2]	03/18/04	6,360,000	NA	NA	--	--
AC[2]	04/08/04	6,560,000	NA	NA	--	--
AC[2]	06/04/04	3,400,000	NA	NA	<3,330	12.0
AD[2]	01/14/04	220,000	NA	NA	--	--
AD[2]	02/17/04	400,000	NA	NA	--	--
AD[2]	03/03/04	420,000	NA	NA	--	--
AD[2]	04/06/04	542,000	NA	NA	--	--
AD[2]	05/04/04	624,000	NA	NA	5,800	65
AD[2]	05/11/04	599,000	NA	NA	--	--
AD[2]	05/19/04	610,000	NA	NA	<3,330	109
AD[2]	06/03/04	744,000	NA	NA	<3,330	70.8

Notes:

ug/L	Micrograms per liter
mg/L	Milligrams per liter
pCi/L	Picocuries per liter
2	Reported analytical results are from Salem Chemistry. Groundwater samples were not submitted to Maplewood for additional analysis.
65	Constituent was detected above the laboratory method detection limit.

220,000	Constituent was detected above its New Jersey Groundwater Quality Criteria.
NA	Not Available - Deviation and LLD for Salem Chemistry are not reported.
--	Constituent not analyzed.

Table 01. Recent Groundwater Analytical Results, PSEG Nuclear, LLC, Salem Generating Station, Hancock's Bridge, New Jersey.

Well Identification	Sample Date	Tritium			Major Cations and Anions	
		Result (pCi/L)	Deviation (pCi/L)	LLD (pCi/L)	Boron (ug/L)	Sodium (mg/L)
AE	01/14/04	16,100	229	144	--	--
AE	02/09/04	16,600	232	139	--	--
AE	03/03/04	17,000	237	147	--	--
AE	03/18/04	19,000	248	145	--	--
AE	04/28/04	14,900	220	140	90	8
AE[1]	05/03/04	14,000	NA	NA	--	--
AF	01/06/04	366	90.2	142	--	--
AF	01/20/04	262	89.3	143	--	--
AF	02/02/04	295	90.6	144	--	--
AF	03/18/04	150	88.0	144	--	--
AF	04/20/04	247	87.8	141	480	654
AF	05/03/04	308	88.6	141	--	--
AG-Shallow	02/23/04	2,320	115	138	40	348
AG-Shallow	03/09/04	3,000	126	146	--	--
AG-Shallow	03/29/04	4,810	150	153	--	--
AG-Shallow	04/12/04	6,620	161	143	260	319
AG-Shallow	04/20/04	8,060	173	142	230	338
AG-Shallow	04/28/04	10,300	188	136	190	312
AG-Shallow	05/10/04	9,580	184	139	--	--
AG-Shallow[2]	05/24/04	10,400	NA	NA	--	--
AG-Shallow[2]	05/26/04	11,300	NA	NA	--	--
AG-Shallow[2]	05/27/04	18,300	NA	NA	--	--
AG-Shallow[2]	05/28/04	14,400	NA	NA	--	--
AG-Shallow[2]	06/03/04	25,400	NA	NA	--	--
AG-Shallow[2]	06/08/04	10,800	NA	NA	--	--

Notes:

ug/L	Micrograms per liter
mg/L	Milligrams per liter
pCi/L	Picocuries per liter
1	Reported analytical results are from Salem Chemistry. Analytical results from Maplewood are pending.
2	Reported analytical results are from Salem Chemistry. Groundwater samples were not submitted to Maplewood for additional analysis.
2,320	Constituent was not detected above the laboratory detection limit.

762	Constituent was detected above the laboratory method detection limit.
25,400	Constituent was detected above its New Jersey Groundwater Quality Criteria.
NA	Not Available - Deviation and LLD for Salem Chemistry are not reported.
--	Constituent not analyzed.

Table 01. Recent Groundwater Analytical Results, PSEG Nuclear, LLC, Salem Generating Station, Hancock's Bridge, New Jersey.

Well Identification	Sample Date	Tritium			Major Cations and Anions	
		Result (pCi/L)	Deviation (pCi/L)	LLD (pCi/L)	Boron (ug/L)	Sodium (mg/L)
AG-Deep	02/23/04	6,100	156	140	340	849
AG-Deep	03/09/04	3,277	132	149	--	--
AG-Deep	03/29/04	2,540	125	151	--	--
AG-Deep	04/12/04	4,990	145	141	510	765
AG-Deep	04/19/04	2,920	124	141	500	868
AG-Deep	04/28/04	896	94.5	135	380	866
AG-Deep[2]	05/03/04	<5,590	NA	NA	--	--
AG-Deep	05/10/04	1,490	106	140	--	--
AG-Deep[2]	05/24/04	<4,560	NA	NA	--	--
AG-Deep[2]	05/28/04	<4,560	NA	NA	--	--
AG-Deep[2]	06/03/04	6,010	NA	NA	--	--
AG-Deep[2]	06/08/04	13,700	NA	NA	--	--
AH-Shallow	02/23/04	899	98.8	143	140	135
AH-Shallow	03/08/04	894	98.2	142	--	--
AH-Shallow	03/29/04	878	97.3	141	--	--
AH-Shallow	04/20/04	932	98.4	141	250	67
AH-Shallow	05/03/04	908	98.0	141	--	--
AH-Shallow[1]	06/03/04	<4,560	NA	NA	--	--
AH-Deep	02/23/04	548	93.3	142	210	309
AH-Deep	03/08/04	620	94.7	142	--	--
AH-Deep	03/29/04	522	92.8	142	--	--
AH-Deep	04/19/04	563	92.5	140	190	241
AH-Deep	05/03/04	637	94.6	142	--	--
AH-Deep[1]	06/03/04	<4,560	NA	NA	--	--

Notes:

ug/L	Micrograms per liter
mg/L	Milligrams per liter
pCi/L	Picocuries per liter
1	Reported analytical results are from Salem Chemistry. Analytical results from Maplewood are pending.
2	Reported analytical results are from Salem Chemistry. Groundwater samples were not submitted to Maplewood for additional analysis.
<5,590	Constituent was not detected above the laboratory detection limit.
548	Constituent was detected above the laboratory method detection limit.

NA Not Available - Deviation and LLD for Salem Chemistry are not reported.
-- Constituent not analyzed.

Table 01. Recent Groundwater Analytical Results, PSEG Nuclear, LLC, Salem Generating Station, Hancock's Bridge, New Jersey.

Well Identification	Sample Date	Tritium			Major Cations and Anions	
		Result (pCi/L)	Deviation (pCi/L)	LLD (pCi/L)	Boron (ug/L)	Sodium (mg/L)
AI[2]	02/02/04	<5,780	NA	NA	--	--
AI	02/26/04	4,360	138	140	50	8
AI	03/11/04	4,370	141	145	--	--
AI	03/30/04	3,550	131	143	--	--
AI	05/04/04	11,800	200	140	--	--
AI[2]	05/11/04	40,800	NA	NA	--	--
AI[2]	05/19/04	44,100	NA	NA	<3,330	47
AI[2]	06/03/04	45,900	NA	NA	--	--
AJ	02/25/04	1,150	102	142	620	616
AJ	03/09/04	1,040	99.1	140	680	650
AJ	03/30/04	1,080	103	146	620	642
AJ	04/19/04	1,190	101	139	670	621
AJ	05/10/04	1,240	103	142	--	--
AJ[1]	05/24/04	<4,560	NA	NA	--	--
AL	02/25/04	<141	83.3	141	210	60
AL	03/09/04	<147	86.1	147	--	--
AL	03/30/04	<146	85.8	146	220	63
AL	04/19/04	<141	85.3	141	300	62
AL[1]	05/19/04	<5,780	NA	NA	--	--
AM[2]	02/26/04	273,000	NA	NA	--	--
AM[2]	03/11/04	234,000	NA	NA	--	--
AM[2]	04/08/04	196,000	NA	NA	--	--
AM[2]	05/06/04	150,000	NA	NA	--	--
AM[2]	05/20/04	149,000	NA	NA	<3,330	6

Notes:

ug/L Micrograms per liter

mg/L Milligrams per liter

pCi/L Picocuries per liter

1 Reported analytical results are from Salem Chemistry. Analytical results from Maplewood are pending.

2 Reported analytical results are from Salem Chemistry. Groundwater samples were not submitted to Maplewood for additional analysis.

<141	Constituent was not detected above the laboratory detection limit.
1,150	Constituent was detected above the laboratory method detection limit.
40,800	Constituent was detected above its New Jersey Groundwater Quality Criteria.
NA	Not Available - Deviation and LLD for Salem Chemistry are not reported.
--	Constituent not analyzed.

Remedial Action Work Plan

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

July 2004

PREPARED FOR

PSEG Services Corporation
80 Park Plaza
Newark, NJ 07102

ARCADIS

Remedial Action Work Plan

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

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

Our Ref:
NP000571.0004

Date:
July 2004

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Executive Summary

ARCADIS, Inc. (ARCADIS), on behalf of PSEG Services Corporation ("PSEG SC"), has prepared this Remedial Action Work Plan ("RAWP") to present the proposed approach for the remediation of groundwater at the PSEG Nuclear, LLC Salem Generating Station (the "Station") located on Artificial Island in Lower Alloways Creek Township, Salem County, New Jersey. The remedial action is being conducted in response to the detection of tritium in groundwater at concentrations above the New Jersey Groundwater Quality Criterion of 20,000 picocuries per liter (pCi/L). Investigations conducted to identify the source of the tritium indicated that the tritium in groundwater was a result of a release of water from the Salem Unit 1 Spent Fuel Pool. This RAWP has been prepared in accordance with the Technical Requirements for Site Remediation N.J.A.C. 7:26E.

PSEG SC completed a remedial investigation of groundwater at the station in March 2004. The remedial investigation was conducted in accordance with the scope of work that was presented in the Remedial Investigation Work Plan ("June 2003 RIWP") submitted to the New Jersey Department of Environmental Protection Bureau of Nuclear Engineering ("NJDEP-BNE") in June 2003, and was later modified in the Initial Groundwater Investigation Report and Remedial Investigation Work Plan Addendum ("RIWP Addendum") submitted in January 2004.

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 29 monitoring wells (see Figure ES-1); 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 and iodine-129 as a means to attempt 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.

In April 2004, the Remedial Investigation Report ("RIR") was submitted to the NJDEP-BNE presenting the results of the remedial investigation as outlined in the June 2003 RIWP and RIWP Addendum. The remedial investigation produced a comprehensive body of knowledge that was used as the basis for developing the remedial action strategy proposed in this RAWP. The objectives of the remedial action are to hydraulically contain the further migration of tritium in groundwater and to reduce the concentration of tritium in groundwater. Groundwater extraction is recommended as the remedial alternative for achieving these objectives. The following sections present a brief overview of the results of the remedial investigation as presented in the RIR, the results of ongoing groundwater investigation activities conducted subsequent to the submittal of the RIR, the proposed remedial action, the results of a well search, and the details of a proposed classification exception area.

Summary of the Remedial Investigation Findings

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. PSEG has continued, and will continue throughout the ensuing groundwater remediation, to evaluate data (e.g., groundwater analytical results and water level data) collected subsequent to the RIR to provide regulatory and public confidence that the source of tritium in groundwater has been accurately identified, has been corrected, and continues to be contained within the boundaries of the facility.

The following bullets provide a detailed description of the remedial 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 have been installed on Salem Units 1 and 2, to permit identification, sampling, and drainage of any accumulated groundwater in the seismic gap, and to create an ingradient to the gap. Since its installation, periodic operation of the seismic gap drain in Unit 1 has resulted in the recovery of as many as 500 gallons of tritiated water each time the drain is operated and Unit 2 has little to no water recovered with no indication that Spent Fuel Pool water is or was present. The concentrations of tritium in the water recovered in the Unit 1 drain have been significantly higher than those indicated by Well AC and Well AM located to the southeast and southwest of the seismic gap, respectively. The Unit 1 seismic gap drain is effectively capturing residual Spent Fuel Pool water in the seismic gap, and will ultimately result in the reduction of tritium concentrations in groundwater adjacent to the seismic 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 locations of the monitoring wells installed to investigate the release of water from the Spent Fuel Pool are shown on **Figure ES-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. The shape of the tritium plume, the direction of groundwater flow, and the presence of boron in groundwater and relatively high concentrations of tritium (e.g., Well AC) are evidence that support the conclusion that water from the Spent Fuel Pool is the source of tritium in groundwater, and the pathway to the environment was the seismic gap. 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 circulating water discharge pipes. **Figure ES-2** shows the area of groundwater indicating concentrations tritium above the New Jersey Groundwater Quality Criterion of 20,000 pCi/L. Groundwater with tritium at concentrations exceeding any regulatory limit has not migrated to the property boundary of the Station;

- Elevated levels of tritium (above the "further action criterion") have only been detected in groundwater samples collected from the shallow, water-bearing unit. There is no evidence to date 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. Groundwater samples collected from the wells screened in the Vincentown Formation indicate ambient concentrations of technitium-99 and ratios of iodine-129/iodine (technetium-99 and iodine-129 are potential Spent Fuel Pool tracers) and no plant related gamma-emitting isotopes ; 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.

Summary of Ongoing Groundwater Investigation Findings

Groundwater investigation activities conducted subsequent to the submittal of the RIR include the analysis of groundwater samples from select monitoring wells for iodine-129 ("^{129}I"), ongoing groundwater monitoring activities, and the preparation of a numerical model using MODFLOW. The following sections provide an overview of the findings of the recent groundwater investigation activities

Iodine-129 Analysis

The potential sources of tritium detected in groundwater samples collected from the monitoring wells at the Station (particularly those screened in the Vincentown Formation) were investigated through the analysis of the radioactive tracer iodine-129 (^{129}I). Tritium and ^{129}I, which is a long-lived radioactive isotope of iodine (15.7 million year half life), typically behave as "conservative" (non-reactive) tracers in groundwater in the absence of high concentrations of organic matter. To differentiate among possible sources of tritium at Salem (i.e., primary versus secondary sources), the ratio of the absolute concentrations of the two tracers were evaluated. Generally, water associated with the Spent Fuel Pool, a "primary" source of tritium, will have relatively high concentrations of both tritium (200,000,000 pCi/l) and ^{129}I (10^{11} atoms/liter; leached from uranium fuel rods). Water from "secondary" sources (e.g. condensed turbine steam) typically have elevated tritium concentrations (10,000 µpCi/l) but near background concentrations of ^{129}I ($<10^{6}$ atoms/liter).

Groundwater samples collected from monitoring wells Well K, Well L, Well P, Well Q, Well N and Well O were analyzed for ^{129}I to evaluate if the Spent Fuel Pool is the likely source of the tritium indicated by these wells. Samples were also collected from

Production Wells PW-3 and PW-6 to determine if the release of water from the Spent Fuel Pool has impacted these wells. Analytical results of groundwater samples collected from these select monitoring and production wells indicate concentrations of ^{129}I (atoms/liter) and $^{129}I/I$ ratios that are typical for waters in the northeastern United States. There is no evidence of an addition of an ^{129}I rich component such as water from the Spent Fuel Pool. This is especially apparent for groundwater samples collected from the wells screened in the Vincentown Formation (Well K, Well L, Well P, and Well Q) and supports the assessment based on the groundwater age, ambient levels of technetium-99, background gamma-emitting isotopes and groundwater modeling that water from the Spent Fuel Pool has not migrated to the Vincentown Formation.

The ^{129}I analysis was initiated as one investigatory tool to identify a potential source of the tritiated groundwater. The ^{129}I analysis was performed at Purdue University, which has limited analytical availability. As concluded in the RIR, there is adequate evidence to conclude that the source of the tritiated groundwater in the shallow, water bearing zones proximal to Salem Unit 1 is the Spent Fuel Pool based on other lines of evidence (e.g., significantly elevated concentrations of tritium and boron). The difficulties associated with the laboratory availability to conduct ^{129}I analysis and the evidence of the source of tritium from other analyses were the basis for the decision not to further pursue additional ^{129}I analysis.

Ongoing Groundwater Monitoring

Groundwater monitoring activities have been ongoing since February 2003 following the installation of Wells K through R. The sampling program is being adaptively managed to ensure representative data are collected that meet the objectives of the investigation/remediation and provide the information necessary to evaluate plume dynamics and migration. Currently, the sampling program design for the Station monitoring wells consists of biweekly, monthly or quarterly sampling.

Groundwater samples are analyzed for tritium and gamma-emitting isotopes. Groundwater samples collected from the recently installed monitoring wells (Wells AG through AM) have also been analyzed for sodium and boron. The large volume of analytical data indicates that gamma-emitting isotopes above background have not migrated beyond the seismic gap area. Analytical results of groundwater samples collected from wells other than the recently installed monitoring wells (Wells AG through AM) are consistent with historic analytical results with the following exception:

- Analytical results of groundwater samples collected from Well O have consistently indicated concentrations of tritium above the further investigation criterion (3,000 pCi/L); however, until January 2004, groundwater samples collected from Well O

did not indicate concentrations of tritium above the further action criterion (20,000 pCi/L). Analytical results of groundwater samples collected since January 2004 have indicated tritium concentrations between 21,000 and 24,200 pCi/L. The cause of the increase in tritium concentrations is being evaluated.

Analytical results of groundwater samples collected from the more recently installed monitoring wells (Wells AG through AM), which were not available at the time the RIR was submitted, indicate the following:

- Groundwater samples collected from Wells AH-Shallow, AH-Deep, AJ, and AL have not indicated concentrations of tritium above the interim further investigation criterion of 3,000 pCi/L; and

- Groundwater samples collected from Wells AG-Shallow, AG-Deep, and AI have indicated concentrations of tritium above the interim further investigation criterion of 3,000 pCi/L but not above the further action criterion of 20,000 pCi/L with the exception of a single sample collected from Well AG-Shallow; and,

- Groundwater samples collected from Well AM have indicated concentrations of tritium above the further action criterion of 20,000 pCi/L.

Preliminary results indicate that the implementation of the pilot study program has, as designed, changed the groundwater flow patterns in the shallow water-bearing unit near the pumping wells. The change in groundwater flow patterns will result in varying tritium concentrations as indicated by groundwater samples collected from monitoring wells within the area of influence of the pumping wells. Although there may be some indicated increases in tritium concentration at a specific well, the ultimate effect is the removal of tritium from the shallow water-bearing unit and the containment of further migration of tritium.

Figure ES-2 shows the extent of tritium indicating concentrations of tritium above 20,000 pCi/L based on the results of the recent groundwater monitoring results

Groundwater Modeling

In accordance with the scope of work outlined in the June 2003 RIWP, a three-dimensional numerical groundwater model has been developed for simulating groundwater flow conditions at the site. The primary objective of this modeling study is to develop groundwater flow and solute transport models to better understand the current nature, extent, and fate of tritium in groundwater, and to support the overall assessment of remediation alternatives to control potential migration of tritium to surface waters.

Modeling results provide information that will be used to quantify environmental conditions (i.e., analysis of potential surface water impacts from groundwater seepage) and evaluate potential remedial actions.

Three solute transport scenarios were evaluated for the movement of tritium at the Site and each are described below. All transport simulations were initialized using the most recent observed tritium concentrations data available at the time the RIR was submitted (March 2004). Each transport scenario was simulated over a 10 year period and is described as follows:

1. **Scenario 1: Existing Conditions** – no active remediation was performed and the plume was assessed to determine, if and at what levels tritium would discharge at the site boundary

2. **Scenario 2: Pilot Study Wells Pumping** – long term groundwater pumping using only the 4 wells selected for the groundwater pump and treatment pilot study.

3. **Scenario 3: Full Scale Remediation** – long term groundwater pumping using a total of 9 wells.

The results from scenario one show that if no action is taken, the majority of the tritium plume will eventually discharge to the Delaware River, predicating the need for active remediation. Scenario 2 shows that the four pilot study wells can control the movement of tritium; however, as the pilot study is not designed or intended to be a full scale remedial system, it does not efficiently recover tritiated groundwater. After 10 years, the pilot study wells have extracted 7.22 curies of tritium, representing approximately 73 % of the current plume (conservatively assumed to be 9.84 curies), and only 7.8 % of the 2004 tritium plume is still in the ground (the remaining balance is a function of natural decay). Scenario 3 shows that full scale remediation utilizing nine recovery wells will be more efficient in the short term and better ensure on-site capture of groundwater as they extract more water, however, in the long term full scale remediation will on only be marginally more effective at removing tritiated groundwater. After 10 years, the full scale remediation system consisting of nine wells have extracted 7.83 curies of tritium, representing approximately 80 % of the current plume of 9.84 curies, and only 4.3 % of the 2004 tritium plume is still in the ground (similarly, the remaining balance is a function of natural decay).

Remedial Alternative Selection

The objectives for the remedial action being conducted at the Station are as follows: 1) Demonstrate hydraulic containment of the tritium plume detected in the shallow, water-bearing unit; and, 2) Capture/Recover tritiated groundwater in the shallow, water-bearing

unit and dispose of the water in accordance with the Station's USNRC license. Groundwater extraction is recommended as the remedial alternative for accomplishing these tasks. To evaluate the effectiveness of groundwater extraction for achieving the objectives of the remedial actions and to evaluate full-scale design of a groundwater extraction system, a pilot study is being performed from April through December 2004.

The pilot study will initially consist of the extraction of groundwater from Wells AB, AC, AD, and AI. Additional locations may be utilized for groundwater extraction throughout the duration of the pilot-study to provide the data necessary to support the design and operation of the full-scale groundwater extraction system. Groundwater extracted from the wells utilized during the pilot-study will be temporarily stored in an 18,000-gallon storage tank pending characterization and subsequent disposal in accordance with the Station's USNRC license.

Based on the results of pumping tests performed on Wells AB, AC, AD, and AI, the combined maximum sustainable yield is expected to be approximately three gallons per minute (gpm). At a pumping rate of three gpm, the storage tank will reach capacity after approximately four days of pumping. Once the storage tank reaches capacity, the pumps in the groundwater extraction wells will be temporarily shut-off while the water in the tank is characterized and the water is disposed. According to Station personnel, the characterization and disposal process should require approximately one to two shifts (8 to 16 hours). Based on this schedule, approximately 18,000 gallons of tritiated groundwater will be extracted and processed approximately every five days, Station operational conditions permitting.

Data collected during the pilot study will include: 1) the routine monitoring of pumping rates and total effluent from the individual wells and within the temporary storage tank; 2) the evaluation of water levels in observation wells located adjacent to the extraction wells to demonstrate that groundwater extraction can hydraulically control the migration of the tritium in groundwater; and, 3) the periodic collection and analysis of groundwater samples from the extraction/observation wells and water samples from the temporary storage tank to demonstrate that through groundwater extraction, tritium concentrations are being reduced.

Following completion, the data obtained during the groundwater extraction pilot study will be evaluated to determine the effectiveness of the selected remedial alternative for achieving the remedial objectives and will be used for full-scale system engineering and operational design. Modifications currently anticipated for the full-scale groundwater extraction system include the following: 1) expansion of the pilot-study extraction well network to include other wells within the area of tritium exceeding the Further Action Criterion; 2) expansion of the capacity of the groundwater extraction system; 3) the design, construction and use of a mobile groundwater extraction unit for temporary/short term pumping at well locations not permanently plumbed to the full-scale system; and, 4) adjustments to the data collection schedule to support the full-scale system.

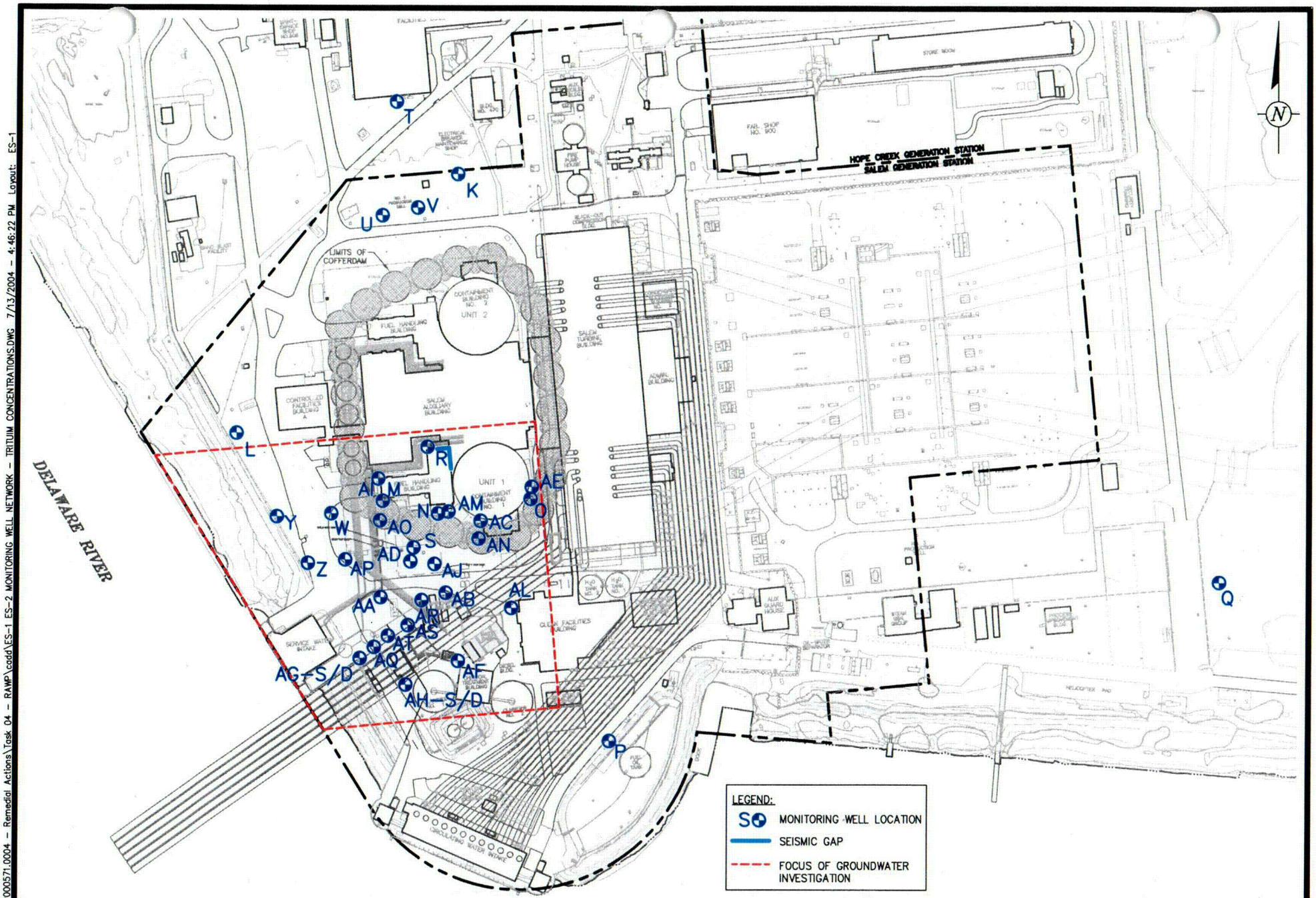
The ongoing groundwater remediation at the Station will be adaptively managed to routinely improve the performance of the full-scale groundwater extraction system. The full-scale design will allow for the flexibility to pump from all or only a limited number of wells within the extraction well network, which is anticipated to be expanded to include as many as 12 extraction wells. The use of a mobile groundwater extraction system will provide additional flexibility. The groundwater extraction system will be operated until PSEG can demonstrate that concentrations of tritium have been reduced to below the Further Action Criterion of 20,000 pCi/L. Upon completion of the remedial action, PSEG will prepare a Remedial Action Report that will include recommendations to: 1) decommission the groundwater extraction system; 2) to abandon the monitoring/extraction wells associated with this remedial action; and, 3) solicit the NJDEP to remove the Classification Exception Area and its obligations (see Section 6).

Well Search Results

In accordance with N.J.A.C. 7:26E-3.7, a well search was conducted to identify all monitoring wells within a one-half mile radius of Salem Unit 1, and all irrigation, industrial, public supply wells, and wells with water allocation permits within a one mile radius. Based on available information, six public supply wells (PW-2, PW-3, PW-5, PW-6, HC-1, and HC-2) and three monitoring wells (OW-6, OW-G, and OW-J) are located within a one-half mile radius of Salem Unit 1. Additionally, one monitoring well (OW-1) is located beyond the one-half mile radius of Salem Unit 1 but within a one-mile radius. All wells identified by PSEG Nuclear, LLC within a one-mile radius are on Station controlled land.

Classification Exception Area

Pursuant to N.J.A.C. 7:9-6, in areas where groundwater contains constituents above GWQC, a Classification Exception Area (CEA) must be established. The shallow water-bearing zone to which this CEA will be applied consists of the hydraulic fill, structural fill, and riverbed deposits of the shallow, water-bearing unit, which range in thickness from 20 to 45 feet. Pursuant to N.J.A.C. 7:9-6.5, groundwater in the area of the Site is presently designated as Class II-A. Constituents that have been identified in Site groundwater above New Jersey Class II-A ground water quality criteria (GWQC) are limited to tritium. Based on the results of the groundwater modeling activities, it is currently anticipated that the proposed groundwater remediation will conservatively be in operation for ten years. In accordance with N.J.A.C. 7:26E-8.6, the proposed CEA duration and boundaries will be reevaluated and certified on a biennial basis.



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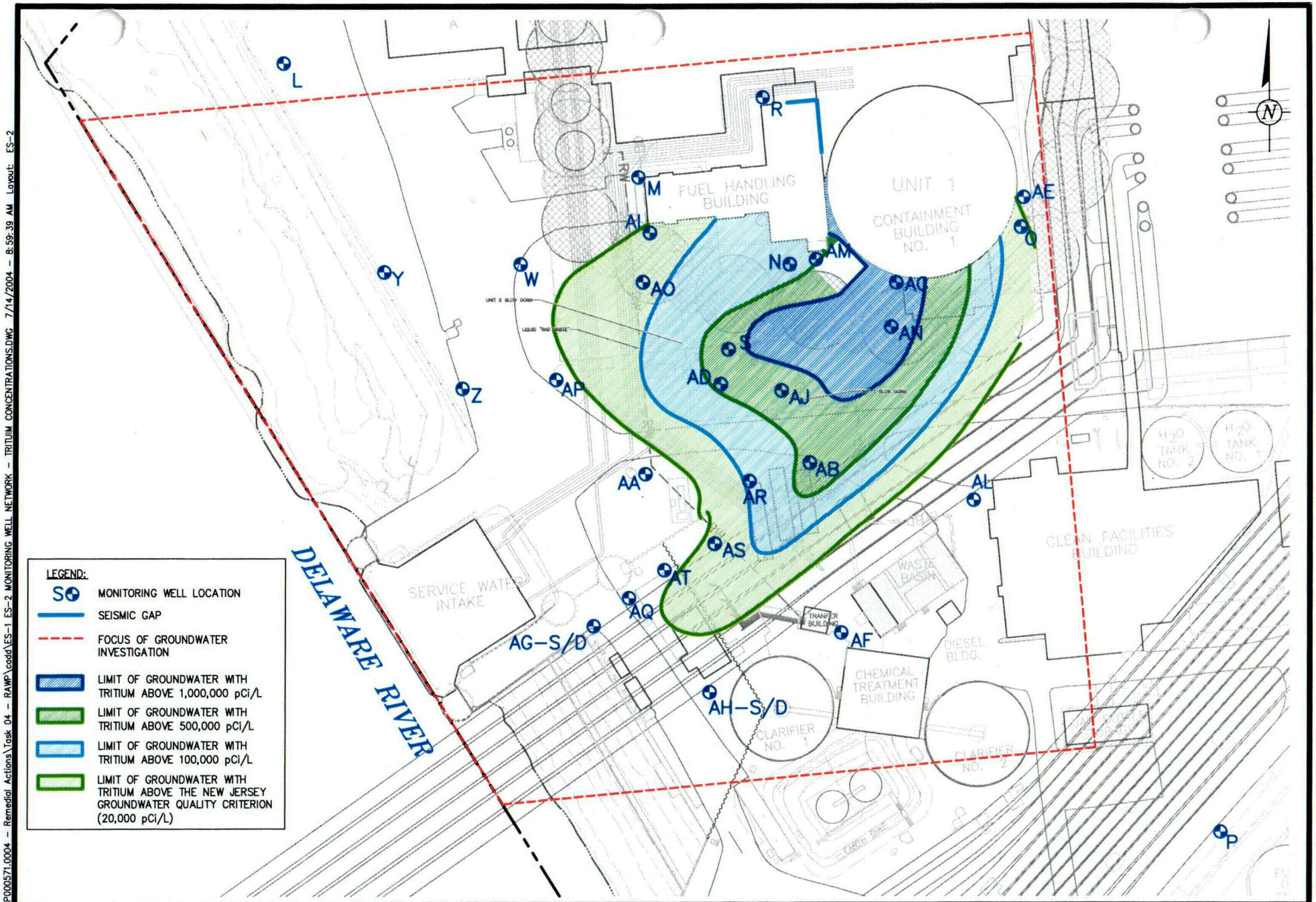
ARCADIS

DRAWN: M. WASILEWSKI	DATE: 6/8/04	PROJECT MANAGER: P. MILIONIS	DEPARTMENT MANAGER: D. FULTON
MONITORING WELL NETWORK		LEAD DESIGN PROF.: S. POTTER	CHECKED: B. PIERCE
PSEG NUCLEAR, LLC SALEM GENERATING STATION ARTIFICIAL ISLAND HANCOCK'S BRIDGE, NEW JERSEY		PROJECT NUMBER: NP000571.0004	DRAWING NUMBER: ES-1



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ARCADIS

DRAWN	DATE	PROJECT MANAGER	DEPARTMENT MANAGER
M. WASILEWSKI	6/8/04	P. MILIONIS	D. FULTON
		LEAD DESIGN PROF. S. POTTER	CHECKED B. PIERCE

AREA OF TRITIUM CONCENTRATIONS ABOVE GWQC

PSEG NUCLEAR, LLC
SALEM GENERATING STATION
ARTIFICIAL ISLAND
HANCOCK'S BRIDGE, NEW JERSEY

PROJECT NUMBER	DRAWING NUMBER
NP000571.0004	ES-2

C014

1 Introduction

ARCADIS, Inc. ("ARCADIS"), on behalf of PSEG Services Corporation ("PSEG SC"), has prepared this Remedial Action Work Plan ("RAWP") to present the proposed approach for the remediation of groundwater 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. This RAWP has been prepared in accordance with the Technical Requirements for Site Remediation, N.J.A.C. 7:26E.

PSEG SC completed a remedial investigation of groundwater at the Station in March 2004. 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-BNE 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.

In April 2004, the Remedial Investigation Report (RIR) was submitted to the NJDEP-BNE presenting 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 of the remedial investigation were used as the basis for the development of the conceptual remedial action strategy that is presented in this RAWP.

As described in Section 4.2, a groundwater extraction pilot-study is ongoing at the facility to collect the data necessary for the design and ongoing operation of the full-scale groundwater extraction system, and in accordance with N.J.A.C. 7:26E-6.3(a), to initiate actions needed to prevent the further migration of tritium. The full-scale system, which is discussed in Section 4.3, will be adaptively managed throughout the duration of the groundwater remediation to effectively control the migration of tritium in groundwater and to reduce concentrations of tritium in groundwater.

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.

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 age of the leak, and to evaluate the 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.

On January 31, 2003, a fiber optic examination of the telltale drains indicated a blockage by mineral deposits of 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 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 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 indicated that the likely source of the water was the Spent Fuel Pool.

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. 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.

Permanent seismic gap drains have been installed on Salem Units 1 and 2, to permit identification, sampling, and drainage of any accumulated groundwater in the seismic gap, and to create an ingradient to the gap. Since its installation, periodic operation of the seismic gap drain in Unit 1 has resulted in the recovery of as many as 500 gallons of tritiated water each time the gap is drained and Unit 2 has little to no water recovered with no indication that Spent Fuel Pool water is or was present. The concentrations of tritium in the water recovered in the Unit 1 drain have been significantly higher than those indicated by Well AC and Well AM located to the southeast and southwest of the seismic gap, respectively. The Unit 1 seismic gap drain is effectively capturing residual Spent Fuel Pool water in the seismic gap, and will ultimately result in the reduction of tritium concentrations in groundwater adjacent to the seismic gap.

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 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.

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.

1.2 Summary of Remedial Investigation

The following sections present an overview of the details and results of the remedial investigation conducted at the Station following the detection of tritium in groundwater adjacent to the Salem Unit 1 Fuel Handling Building. Investigation activities included the installation and sampling of groundwater monitoring wells, the delineation of tritium in groundwater through a supplemental investigation, various hydrogeologic investigations, fate and transport analyses, and a health and environmental risk assessment.

1.2.1 Well Installation, Groundwater Sampling and the Supplemental Investigation

Initially, the investigation included the installation and sampling of eight monitoring wells and/or direct-push groundwater sampling locations identified as Well K through Well R; Well M and Well R being direct-push sampling locations. 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).

To evaluate the extent of tritium in groundwater above the GWQC, Wells S through W were installed between May 5 and June 18, 2003 and existing Wells M and R were replaced with properly constructed and developed monitoring wells. **Figure 3** shows the monitoring well network installed during the remedial investigation. Construction details and other pertinent information regarding the monitoring wells installed throughout the remedial investigation are summarized in **Table 1.**

Following installation and development of the new monitoring wells, groundwater samples were collected from the wells and analyzed by Maplewood Testing Services (Maplewood) and/or Salem Chemistry for tritium, sodium, boron, and gamma-emitting isotopes. All samples were non-detect for plant related 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.

The supplemental groundwater investigation consisted of 37 proposed boring locations, seven of which could not be advanced due to subsurface structural interferences. Groundwater samples were collected from the borings from as many as three depths at each location. The borings were proposed for the following reasons: 1) to evaluate concentrations along the site perimeter to assess the potential for off-site migration; 2) near Station infrastructure to identify possible sources of tritium (e.g., the liquid radioactive waste line, the Unit 1 Spent Fuel Pool, the Unit 1 refueling water storage tank, and the Unit 1 primary water storage tank); and, 3) in the vicinity and downgradient of Well S to determine the extent of tritium in groundwater.

The findings from the supplemental investigation delineated an area of tritium in groundwater above the GWQC for tritium (20,000 pCi/L); however, a completed pathway between a potential source and groundwater was not identified. Although a completed pathway between a potential source and groundwater was not identified during the supplemental investigation, tritium concentrations and groundwater flow direction indicated that the southern end of the seismic gap was the likely source of tritium in groundwater. Additionally, extensive on-site monitoring of shallow groundwater indicates that tritium in groundwater has not migrated to the Station boundary above permissible levels.

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.

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, which is discussed in Section 3.2, 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). Technetium-99 (Tc-99) and iodine-129 (^{129}I) were also analyzed as a single-event analysis for select monitoring wells to assist in the determination of the source of the tritium. Analytical results of groundwater samples collected during the remedial investigation are discussed in the following section.

1.2.2 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) were 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 4**).

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 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 Fuel Handling 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.

1.2.3 Hydrogeologic Investigation

The following sections provide the details and results of the site-specific hydrogeologic investigation activities conducted during the remedial investigation. 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; and, the performance of slug tests and pumping tests on various monitoring wells. A more detailed description of the Station geology and hydrogeology is provided in the March 2004 RIR.

1.2.3.1 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 monitoring wells screened in the shallow, water-table aquifer are periodically monitored to evaluate groundwater flow conditions in this unit. The details and results of measurements collected subsequent to the completion of the remedial investigation are presented in Section 3.2.3.

1.2.3.2 Aquifer Pumping Tests

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.

1.2.4 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.

1.2.5 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.

1.3 Report Organization

This report provides relevant background information, updates the details and results of additional remedial investigation activities, the proposed remedial action, the results of a well search, and in the following sections:

- Section 2 – Constituents of Concern and Applicable Cleanup Criteria;
- Section 3 – Ongoing Groundwater Investigation Activities;
- Section 4 - Remedial Alternative Selection;
- Section 5 – Well Search Results;
- Section 6 – Classification Exception Area;
- Section 7 – Groundwater Monitoring Plan

The Constituents of Concern and Applicable Criteria section (Section 2) presents information regarding the constituent of concern (i.e., tritium) that has resulted in the need for a remedial action, and the applicable criteria that have been established for guiding the investigation and remediation of groundwater.

The Ongoing Groundwater Investigation Activities section (Section 3) presents the results of groundwater activities conducted since the submittal of the Remedial Investigation Report in March 2004. These activities include the results of ^{129}I analysis performed on groundwater samples collected from select monitoring wells, the details and results of ongoing groundwater monitoring activities, and the details and results of a groundwater model prepared using MODFLOW.

The Remedial Alternative Selection section (Section 4) presents an overview and the objectives of the selected remedial alternative (groundwater extraction). This section also presents the details of the ongoing pilot study being conducted to evaluate the effectiveness of the selected remedial alternative and to assist in the design of the full-scale remediation system.

The Well Search section (Section 5) presents the results of a well search conducted in accordance with New Jersey Administrative Code (N.J.A.C.) 7:26E.

The Classification Exception Area section (Section 6) provides the documentation for establishing a Classification Exception Area (CEA).

The Groundwater Monitoring Plan section (Section 7) presents the proposed groundwater monitoring plan that will be employed throughout the proposed groundwater extraction program.

2 Constituents of Concern and Applicable Criteria

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 2**. 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.

The primary constituent of concern for this remedial action 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, action levels were defined for tritium in groundwater to assist in the evaluation of data generated through the investigation and the need for remediation. One of these action levels was the Further Action Criterion of 20,000 pCi/L, which is the New Jersey Groundwater Quality Criteria for tritium in Class II A aquifers. The Further Action Criterion for tritium was established to trigger a remedial action if exceeded, and through the remedial investigation, the area containing groundwater above 20,000 pCi/L was delineated.

As stated previously, a pilot-study is ongoing to evaluate the effectiveness of groundwater extraction for capturing tritium in groundwater above 20,000 pCi/L and reducing tritium concentrations to below this action level. The details of the pilot-study are presented in

Section 4.2. Based on data collected through the pilot-study, a full-scale groundwater extraction system will be designed, installed and operated (see Section 4.3 for details). As presented in Section 4.3, the full-scale system, once implemented, will be adaptively managed to continuously refocus the specific extraction scheme to meet the remedial objectives. The full-scale groundwater extraction system will be operated until it can be demonstrated that concentrations of tritium have been remediated to below 20,000 pCi/L.

As required by N.J.A.C. 7:9-6.6, a Classification Exception Area (CEA) must be established to define the area of groundwater containing constituents above the applicable New Jersey Groundwater Quality Criteria and to define the longevity of the CEA, which must be maintained until concentrations of those constituents have been remediated to the applicable criteria. The information necessary to establish the CEA is presented in Section 7. The CEA will remain in effect until tritium concentrations in groundwater have been remediated to 20,000 pCi/L. A groundwater model was used to evaluate the potential duration of the groundwater remediation (section 4.3), and based on the results of the model, the proposed CEA duration is 10 years.

In addition to the applicable groundwater quality criterion for tritium outlined above, PSEG Nuclear, LLC is also required to provide notification if other applicable criteria are exceeded. These specific regulatory notification requirements are as follows: (1) USNRC notification if tritium is equal to or exceeds 30,000 pCi/L off site, in accordance with the Offsite Dose Calculation Manual based on 10CFR20 Appendix B, Table 2, Column 2; and, (2) Delaware River Basin Commission (DRBC) notification if surface water conditions in the Delaware River exceeds 1,000 pCi/L gross beta emitting radioactive nuclides [calculations are underway to determine the amount of tritium concentrations required to cause an exceedance of this criteria and what the impact would be in the perimeter well samples. Since normal licensed discharges are not causing violation of the criteria, it is anticipated that the amount of groundwater contamination found at Salem can not cause a violation of this criteria in the River].

3 Ongoing Investigation Activities

The following sections provide the details and results of groundwater investigation activities conducted since the submittal of the March 2004 RIR. These activities include the analysis of groundwater samples from select monitoring wells for ^{129}I, the details and results of ongoing groundwater monitoring activities, and the details of a numerical model prepared using MODFLOW.

3.1 Iodine-129 Analysis

The potential source of tritium detected in groundwater samples collected from the monitoring wells at the Station (particularly those screened in the Vincentown Formation) was investigated through the analysis of the radioactive tracer iodine-129 (^{129}I). Tritium and ^{129}I, which is a long-lived radioactive isotope of iodine (15.7 million year half life), typically behave as "conservative" (non-reactive) tracers in groundwater in the absence of high concentrations of organic matter. To differentiate among possible sources of tritium at Salem (i.e., primary versus secondary sources), the ratio of the absolute concentrations of the two tracers were evaluated. Generally, water associated with the Spent Fuel Pool, a "primary" source of tritium, will have relatively high concentrations of both tritium (200,000,000 pCi/l) and ^{129}I (10^{11} atoms/liter; leached from uranium fuel rods). Water from "secondary" sources (e.g. condensed turbine steam) will have elevated tritium concentrations (10,000 µpCi/l) but near background concentrations of ^{129}I ($<10^{6}$ atoms/liter).

Complicating this scenario is the fact that large quantities of ^{129}I have been released into the environment, dominantly from fuel reprocessing plants such as the plant located in West Valley, New York. Because of the continued presence of ^{129}I from reprocessing in the northeastern United States, anthropogenic ^{129}I additions have swamped the natural budget, resulting in elevated ^{129}I concentrations and $^{129}I/I$ ratios in surface waters (e.g. the Delaware River); however, even with an increased background concentration of ^{129}I, localized releases of water containing elevated levels of ^{129}I (e.g. Spent Fuel Pool water or fuel reprocessing activity) can be observed. The high concentration of ^{129}I in Spent Fuel Pool water (10^{11} atoms/liter) makes it possible to investigate if a release of Spent Fuel Pool water has migrated away from Salem Unit 1 during the past 25 years. To this end, groundwater samples were collected from monitoring wells Well K, Well L, Well P, Well Q, Well N and Well O and Production Wells PW-3 and PW-6. The groundwater samples were analyzed for ^{129}I in accordance with the procedures outlined in the Quality Assurance Project Plan (QAPP), which was included as an appendix to the June 2003 RIWP.

Results of the I-129 ^{129}I analysis and a detailed discussion regarding their significance are presented in **Appendix A**. In general, analytical results of groundwater samples collected from the select monitoring and production wells indicate concentrations of ^{129}I (atoms/liter) and $^{129}I/I$ ratios that are typical for waters in the northeastern United States. There is no evidence of an addition of a ^{129}I rich component typical of the Spent Fuel Pool (especially in the wells from the Vincentown Aquifer). Of the groundwater samples collected from

monitoring wells screened in the Vincentown Formation (Well L, Well K, Well P, and Well Q), three indicate a "pre-nuclear" age based on the low to "non-detect" levels of tritium and low levels of ^{129}I. Well Q indicates a ratio of $^{129}I/I$ typical of modern day surface seawater but is elevated in the concentration of ^{129}I (32 atoms/µl) because of bio-concentration of iodine in organic-rich sediments that surround the plant and the subsequent release to the groundwater during the breakdown of the organic matter by methanogenic bacteria. Thus, the $^{129}I/I$ ratio indicated by Well Q is indicative of surface seawater and the relatively high ^{129}I concentration indicates breakdown of this iodine-rich, organic source. Because groundwater at Well Q indicates a "pre-nuclear" recharge age, anthropogenic ^{129}I (high $^{129}I/I$ ratio) is not observed.

The other wells screened in the Vincentown Formation (Well L, Well P and Well K), all indicate similar ^{129}I concentrations and $^{129}I/I$ ratios (Figure 1). Groundwater at Well K indicates a lower ^{129}I concentration and $^{129}I/I$ than groundwater at Well P, even though groundwater at Well P has twenty times lower tritium. Analytical results of groundwater samples collected from Well K, Well L, and Well P indicate ambient $^{129}I/I$ ratios (from 20 years ago) in this marsh environment and contain no measurable Spent Fuel Pool activity. The $^{129}I/I$ ratios in Well K, Well L and Well P (of 10^{-9}) result from a mixture of iodine from the Delaware River (rich in ^{129}I but low in total iodine) and surface seawater. Organic processes in the marshes adjacent to Salem then concentrate the iodine. Breakdown of organic rich sediments by methanogenic bacteria result in a release of the iodine (and methane) to groundwater. Thus, the $^{129}I/I$ ratios indicated by groundwater samples collected from Well K, Well L and Well P are indicative of a "mixed" source (mixture of river and seawater) and the "elevated" ^{129}I concentrations indicate breakdown of this iodine-rich, organic "mixed" source. Therefore, because groundwater wells that contain background tritium concentrations (i.e., Well L and Well P) have higher ^{129}I concentrations than Well K, which has a slightly elevated tritium concentration, and all other tracers of Spent Fuel Pool activity (e.g., gamma-emitting isotopes and technetium-99) in Well K are at background concentrations, it is concluded that the source of tritium at Well K is not from the Spent Fuel Pool. The age of the tritium, as determined using tritium/helium ratios, and the groundwater modeling also support this conclusion.

Analytical results of groundwater samples collected from Well O and Well N, which are screened in the shallow, water-bearing unit within the limits of the cofferdam indicate a lower percentage of iodine from the Delaware River (lower $^{129}I/I$ ratios than Well K, Well L and Well P) and variable amounts of bio-concentration and release of iodine. As noted in Appendix A, there is a slight indication that a minor amount of Spent Fuel Pool water is present at Well N, but the results are not conclusive.

The ^{129}I analysis was initiated as one investigatory tool to identify a potential source of the tritiated groundwater. The ^{129}I analysis was performed at Purdue University, which has limited analytical availability. As concluded in the RIR, there is adequate evidence to identify the source of the tritiated groundwater is the Spent Fuel Pool based on other lines of evidence (e.g., significantly elevated concentrations of tritium and boron). The difficulties associated with the laboratory availability to conduct ^{129}I analysis and the

evidence of the source of tritium from other analyses was the basis for the decision not to further pursue additional ^{129}I analysis.

3.2 Groundwater Monitoring Activities

Groundwater monitoring activities have been ongoing since February 2003 following the installation of Wells K through R. Groundwater monitoring activities consist of the periodic collection of groundwater samples from the Station monitoring wells, and an evaluation of groundwater flow dynamics through the collection of water levels from the monitoring well network. 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 and gamma emitting isotopes, with select groundwater samples also being analyzed for major cations and anions. 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 K, 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;

- Wells 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, were sampled on a bi-weekly basis until an analytical history was established for these wells and are currently being sampled on a less frequent basis.

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 details of the groundwater monitoring activities and the analytical results of groundwater samples collected through mid-January 2004 were presented in the RIR. The details and results of groundwater sampling activities conducted subsequent to those presented in the RIR through June 2004

are presented in Sections 3.2.1 and 3.2.2, respectively. Details and results of water level measurements collected from the Station monitoring wells are presented in Section 3.2.3.

3.2.1 Groundwater Sampling Methods

To minimize the influence of turbidity, groundwater samples were collected in accordance with the low-flow sampling procedure outlined in the 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 subsequent to those presented in the RIR is provided in **Table 3**.

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.

Since the initiation of the pilot study program, wells which are being utilized for groundwater extraction are not sampled using the methods outlined above, but are sampled directly from the pump effluent.

3.2.2 Groundwater Tritium Results

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. The locations of the monitoring wells are shown on **Figure 3**. Groundwater samples collected from the monitoring wells have been analyzed to assess natural geochemistry, as well as facility-related constituents. 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. Analytical results of groundwater sampling activities conducted through mid-January 2004 were presented in the RIR. Groundwater analytical results for samples collected subsequent to those presented in the RIR through June 2004 are presented in the following paragraphs.

Groundwater samples are submitted to Maplewood and/or Salem Chemistry for analysis. Historically, groundwater samples were analyzed for tritium, major cations and anions (sodium and boron), and gamma-emitting isotopes. A summary of historical analytical results was presented in the RIR. Groundwater samples collected following those presented in the RIR have been analyzed for tritium and gamma-emitting isotopes. Groundwater samples collected from the recently installed monitoring wells (Wells AG through AM) have also been analyzed for sodium and boron. The large volume of analytical data indicates that plant related gamma-emitting isotopes have not been detected in any groundwater samples collected during the groundwater investigation and, thus, have not migrated beyond the seismic gap area. A summary of the recent analytical results obtained from Maplewood and Salem Chemistry is presented in **Table 4**. The recent analytical results for tritium are also presented on **Figure 4**, along with an interpretation of the current distribution of tritium in groundwater.

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.

3.2.2.1 Summary of Tritium Data for Wells Screened in the Vincentown Formation

Groundwater quality in the monitoring wells screened in the Vincentown Formation, which consist of Well K, Well L, Well P, Well Q, and Well V, is currently monitored on a quarterly basis. Groundwater samples collected from these wells are analyzed for tritium and gamma-emitting isotopes. Analytical results of groundwater samples collected from Well L, Well P, and Well Q continue to indicate concentrations of tritium below the

laboratory detection limits. Analytical results of groundwater samples collected from Well V indicated tritium concentrations of 290 pCi/l and 316 pCi/l in March and April 2004, respectively. Analytical results of groundwater samples collected from Well K, which historically have indicated tritium concentrations ranging from 557 to 1,380 pCi/L indicated a tritium concentration of 762 pCi/L in the groundwater sample collected on February 4, 2004

3.2.2.2 Summary of Tritium Data for Wells Screened in the Shallow, Water Bearing Unit Within the Limits of the Cofferdam

Wells screened in the shallow, water-bearing unit within the limits of the cofferdam include Well M, Well N, Well O, Well R, Well AC, Well AE, Well AI, and Well AM. Groundwater samples are collected from these wells periodically, as described in Section 3.2. Historically, 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, R, AC, AE, AI, and AM installed within the limits of the cofferdam. Additionally, analytical results of groundwater samples collected from Well M, N, O, AC and AM have indicated concentrations of tritium above the further action criteria of 20,000 pCi/L. The following provides a summary of the analytical results for the individual wells:

- **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. The original direct-push well point was replaced with a properly constructed well that conforms with New Jersey well construction requirements. The replacement well was constructed with a screened 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 the current concentration of 2,350 pCi/L. Current concentrations are lower than concentrations measured before the well was replaced.

- **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 9,760 pCi/L on June 3, 2004.

- **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). Groundwater samples initially collected from Well O through July 2003 indicated tritium concentrations on the order of 10,000 pCi/L. From July 2003 through January 2004 tritium concentrations indicated by this well steadily decreased. Analytical results of groundwater samples collected since January 2004 have indicated tritium concentrations above the further action criterion (20,000 pCi/L) between 20,400 and 24,200 pCi/L. The cause of the increase in tritium concentrations is being evaluated.

- Well R – Analytical results of groundwater samples collected from Well R have indicated 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 4,800 pCi/L on May 25, 2004.

- Well AC – Analytical results of groundwater samples collected from Well AC, which is located closest to the south end of the seismic gap have indicated the highest concentrations of tritium in Site monitoring wells (15,000,000 pCi/L). Initially following installation, tritium concentrations ranged from 10,700,000 pCi/L and 15,000,000 pCi/L. Since December 2003, tritium concentrations indicated by groundwater samples collected from this well have decreased to 3,400,000 pCi/L.

- Well AE – Analytical results of groundwater samples collected from Well AE have indicated concentrations of tritium at or above the further investigation criterion (3,000 pCi/L). Tritium concentrations have ranged from 5,990 pCi/L to 19,000 pCi/L. Recently, tritium was detected in a groundwater sample collected from Well AE at a concentration of 14,000 pCi/L.

- Well AI – Analytical results of groundwater samples collected from Well AI have initially indicated concentrations of tritium above the further investigation criterion (3,000 pCi/L). Tritium concentrations have been detected at concentrations of approximately 4,300 pCi/L. Well AI is currently being utilized as a groundwater extraction well during the groundwater extraction pilot study (see Section 4.2 for details). As anticipated, , tritium concentrations have steadily increased in Well AI since the initiation of the pilot study in April 2004 from 3,550 pCi/L on March 30, 2004 to 45,900 pCi/L on June 3, 2004.

- Well AM – Analytical results of groundwater samples collected from Well AM have indicated concentrations of tritium above the further action criterion of 20,000 pCi/L. Initial groundwater samples collected from this well have indicated concentrations of tritium of 273,000 and 234,000 pCi/L in February and March 2004, respectively. Since March 2004, tritium concentrations indicated by Well

AM have steadily declined to its current concentration of 149,000 pCi/L on May 20, 2004.

3.2.2.3 Summary of Tritium Data for Wells Screened in the Shallow, Water-Bearing Unit Outside of the Cofferdam

The wells installed in the shallow, water-bearing unit outside of the limits of the cofferdam are screened either just above the clay confining unit, or in the interval indicating the highest tritium concentrations during the Supplemental Investigation. These wells include Well S, Well T, Well U, Well W, Well Y, Well Z, Well AA, Well AB, Well AD, Well AF, Well AG (Shallow and Deep), Well AH (Shallow and Deep), Well AJ, and Well AL. Groundwater samples collected from these wells indicated that tritium has been detected above 3,000 pCi/L (the Interim Further Investigation Criterion for Tritium) in Wells S, W, AB, AD, AG-Shallow, AG-Deep, and AM. Wells S, AB, AD, and AM also have indicated concentrations of tritium above the further action criteria of 20,000 pCi/L. The following provides a summary of the analytical results for the individual wells:

- **Well S** – Groundwater samples collected from Well S indicated concentrations of tritium above the further action criteria for tritium (20,000 pCi/L). Concentrations of tritium in Well S have ranged from 889,000 to 3,530,000 pCi/L with a declining trend over the period of investigation.

- **Well T** – Groundwater samples collected from Well T have been below the further investigation criteria for tritium (3,000 pCi/L). Groundwater samples submitted to Maplewood for analysis have not indicated concentrations of tritium above the laboratory detection limit.

- **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.

- **Well W** – Groundwater samples collected from Well W typically are above the further investigation criterion for tritium (3,000 pCi/L). Tritium results from samples ranged from 2,350 pCi/L to 19,600 pCi/L.

- **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.

- **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 have ranged from non-detect to 729 pCi/L.

- **Well AA** – Tritium concentrations in groundwater samples collected from Monitoring Well AA historically were below the further investigation criterion for tritium (3,000 pCi/L); tritium results from samples sent to Maplewood ranged from 613 pCi/L to 1,130 pCi/L. The groundwater sample collected from Well AA on April 12, 2004 indicated a tritium concentration of 3,140 pCi/L.

- **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 193,000 to 409,000 pCi/L. Tritium concentrations indicated by groundwater samples collected from this well declined from December 2003 through the beginning of May 2004, when tritium was detected at 409,000 pCi/L and 136,000 pCi/L, respectively. Since the initiation of the groundwater extraction pilot study, tritium concentrations have increased to 210,000 pCi/L on June 3, 2004.

- **Well AD** – Groundwater samples collected from Well AD have indicated 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 744,000 pCi/L. Since the initiation of the groundwater extraction pilot study, tritium concentrations have increased from 542,000 pCi/L to 744, 000 pCi/L.

- **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 from samples sent to Maplewood have ranged from non-detect to 330 pCi/L.

- **Well AG-Shallow** – Groundwater samples were initially collected from Well AG-Shallow in February 2004. Initially, tritium was detected at a concentration of 2,230 pCi/L. Tritium concentrations indicated by this well steadily increased from the initial sample to a high concentration of 25,400 pCi/L on June 3, 2004. The groundwater sample collected on June 8, 2004 indicated a tritium concentration of 10,800 pCi/L. Groundwater samples will continue to be collected from this well at a minimum biweekly schedule until tritium concentrations stabilize.

- **Well AG-Deep** – Groundwater samples were initially collected from Well AG-Deep in February 2004. Initially, tritium was detected at a concentration of 6,100 pCi/L. Analytical results of groundwater samples collected subsequent to this sampling event and submitted to Maplewood for analysis have fluctuated between a low concentration of 896 pCi/L and a high concentration of 13,700 pCi/L.

- **Well AH-Shallow** – Groundwater samples were initially collected from Well AH-Shallow in February 2004. Initially, tritium was detected at a concentration of 899 pCi/L. Analytical results of groundwater samples collected subsequent to this sampling event have indicated steady concentrations of tritium from 878 pCi/L to 932 pCi/L.

- **Well AH-Deep** – Groundwater samples were initially collected from Well AH-Deep in February 2004. Initially, tritium was detected at a concentration of 548 pCi/L. Analytical results of groundwater samples collected subsequent to this sampling event and submitted to Maplewood for analysis have indicated steady concentrations of tritium from 522 pCi/L to 637 pCi/L.

- **Well AJ** – Groundwater samples were initially collected from Well AJ in February 2004. Initially, tritium was detected at a concentration of 1,150 pCi/L. Analytical results of groundwater samples collected subsequent to this sampling event and submitted to Maplewood for analysis are below the detection limits for Salem Chemistry. Analytical results from Maplewood are between 1,035 and 1,924 pCi/L.

- **Well AL** - Groundwater samples were initially collected from Well AL in February 2004. Tritium was not detected above the laboratory detection limit at Maplewood for groundwater samples initially collected from this well. Analytical results of groundwater samples collected subsequent to this sampling event remain below the Maplewood detection limit.

3.2.3 Evaluation of Groundwater Flow in the Shallow, Water-Bearing Unit

To characterize groundwater flow conditions in the shallow, water-bearing unit, depth-to-water measurements were collected from the monitoring wells during a synoptic event conducted by ARCADIS personnel on March 19, 2004. A summary of water level measurements collected to date is presented in **Table 5**. The depth-to-water measurements were gauged relative to the top of 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. As summarized in **Table 5**, 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 of the cofferdam.

A groundwater elevation contour map for the shallow, water-bearing unit is presented on **Figure 5**. As shown on the figure, 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 used within the limits of the cofferdam

and the combination of structural and hydraulic fill used outside of the cofferdam, an apparent groundwater mound is observed within the limits of the cofferdam. Groundwater flows radially outward from the cofferdam, and the observed mounding effect dissipates quickly. The March 19, 2004 groundwater elevations and interpreted contours are consistent with previously conducted gauging events.

3.3 Groundwater Modeling

In accordance with the scope of work outlined in the June 2003 RIWP, a three-dimensional numerical groundwater model has been developed for simulating groundwater flow conditions at the site. The primary objective of this modeling study is to develop groundwater flow and solute transport models to better understand the current nature, extent, and fate of tritium in groundwater, and to support the overall assessment of remediation alternatives to control potential migration of tritium to surface waters. Modeling results provide information that will be used to quantify environmental conditions (i.e., analysis of potential surface water impacts from groundwater seepage) and evaluate potential remedial actions.

The development, construction, and calibration of groundwater flow and solute transport models are detailed in **Appendix B**. Existing hydrogeologic Site data was used, along with additional regional information found in the literature, to develop, construct, and calibrate the flow and transport models. Flow and transport simulations were performed to evaluate the future migration of tritium in groundwater beneath the Site. The modeling study focused on groundwater movement in the sands above the clay confining unit (shallow groundwater) to determine if tritium is currently discharging, or has the potential to discharge, to the Delaware River.

MODFLOW, a publicly-available simulation program developed by the U.S. Geological Survey (USGS) (McDonald and Harbaugh, 1988), was selected for the construction and calibration of the groundwater flow model at the Site. MODFLOW is thoroughly documented, widely used by consultants, government agencies and researchers, and is consistently accepted in regulatory and litigation proceedings. In constructing the flow model for the site, representative values for model parameters were selected based on site-specific data. These values were adjusted as the groundwater flow model was calibrated using water-level elevations measured in monitoring wells distributed throughout the Site. After flow calibration, solute transport modeling was used to evaluate the movement of tritium through the groundwater system to determine if tritium will discharge to the Delaware River, and to predict the discharge concentration.

The MT3DMS computer code developed by the U.S. Environmental Protection Agency (Zheng and Wang, 1998) was selected for solute transport modeling. MT3DMS, which uses the MODFLOW groundwater flow and velocity terms in transport calculations, is also a

publicly available computer program that features extensive documentation and verification. MT3DMS also uses the same finite-difference grid structure and boundary conditions as the groundwater flow model, minimizing the effort necessary to construct a solute transport model.

Three solute transport scenarios were evaluated the movement of tritium at the Site and each are described below. All transport simulations were initialized using the most recent observed tritium concentrations data. Each transport scenario was simulated over a 10 year period and is described as follows:

4. **Scenario 1: Existing Conditions** – no active remediation was performed and the plume was assessed to determine, if and at what levels tritium would discharge at the site boundary

5. **Scenario 2: Pilot Study Wells Pumping** – long term groundwater pumping using only the 4 wells selected for the groundwater pump and treatment pilot study.

6. **Scenario 3: Full Scale Remediation** – long term groundwater pumping using a total of 9 wells.

The results from scenario one show that if no action is taken, the majority of the tritium plume will eventually discharge to the Delaware River, predicating the need for active remediation. Scenario 2 shows that the four pilot study wells can control the movement of tritium; however, as the pilot study is not designed or intended to be a full scale remedial system, it does not efficiently recover tritiated groundwater. After 10 years, the pilot study wells have extracted 7.22 curies of tritium, representing approximately 73 % of the current plume (conservatively assumed to be 9.84 curies), and only 7.8 % of the 2004 tritium plume is still in the ground (the remaining balance is a function of natural decay). The total activity in the plume is computed to be between 5.62 and 9.84 curies depending on whether the effective porosity (0.2) or total porosity (0.35) is used in the calculation. Scenario 3 shows that full scale remediation utilizing nine recovery wells will be more efficient in the short term and better ensure on-site capture of groundwater as they extract more water, however, in the long term full scale remediation will on only be marginally more effective at removing tritiated groundwater. After 10 years, the full scale remediation system consisting of nine wells have extracted 7.83 curies of tritium, representing approximately 80 % of the current plume of 9.84 curies, and only 4.3 % of the 2004 tritium plume is still in the ground (similarly, the remaining balance is a function of natural decay).

4 Remedial Alternative Selection

To recover the tritiated groundwater from the shallow, water-bearing unit, and to hydraulically contain the further migration of tritium, remedial actions are required. Currently, groundwater extraction is recommended as the remedial alternative for accomplishing these tasks. To evaluate the full-scale system design of the groundwater extraction system, a pilot-study is currently being conducted. The pilot-study is scheduled for the period of April through December 2004. Data obtained during the pilot study is being evaluated and the full-scale system will be designed and installed and operation will be initiated by the end of 2004 based on the results of the pilot study. Details regarding the proposed remedial alternative are presented in the following sections. These details include the objectives of the remedial actions, an overview of the ongoing pilot study including data requirements for evaluating the effectiveness of groundwater extraction, the transition from pilot-study to full-scale groundwater extraction system, and the schedule for submitting remedial action progress reports.

4.1 Remedial Action Objectives

The objectives for the remedial action being conducted at the Station are as follows:

(1) Demonstrate hydraulic containment of the tritium plume detected in the shallow, water-bearing unit; and,

(2) Capture/Recover tritiated groundwater in the shallow, water-bearing unit and dispose of the water in accordance with the Station's USNRC license.

4.2 Groundwater Extraction Pilot Study

To evaluate the effectiveness of groundwater extraction for achieving the objectives of the remedial actions and to evaluate full-scale design of a groundwater extraction system, a pilot study is being performed from April through December 2004. The pilot study will initially consist of the extraction of groundwater from Wells AB, AC, AD, and AI. Additional locations may be utilized for groundwater extraction throughout the duration of the pilot-study to provide the data necessary to support the design of the full-scale groundwater extraction system. These locations may include existing monitoring wells, but may also include locations currently without an existing well. In the case of the latter new wells will be installed, as necessary.

Groundwater extracted from the wells utilized during the pilot-study will be temporarily stored in an 18,000-gallon storage tank pending characterization and subsequent disposal in accordance with the Station's USNRC license. Based on the results of pumping tests performed on Wells AB, AC, AD, and AI, the combined maximum sustainable yield is expected to be approximately three gallons per minute (gpm). At a pumping rate of three gpm, the storage tank will reach capacity after approximately four days of pumping. Once

the storage tank reaches capacity, the pumps in the groundwater extraction wells will be temporarily shut-off while the water in the tank is characterized and the water is disposed. According to Station personnel, the characterization and disposal process should require approximately one to two shifts (8 to 16 hours). Based on this schedule, approximately 18,000 gallons of tritiated groundwater will be extracted and processed approximately every five days, Station operational conditions permitting. Groundwater extracted during the remedial effort will be temporarily transferred to storage tanks to ensure the monitoring requirements of the Station's United States Nuclear Regulatory Commission (USNRC) operating license are fulfilled prior to disposal.

As stated previously, the pilot study is being conducted to evaluate the effectiveness of groundwater extraction for fulfilling the objectives of the remedial action, which are: 1) the hydraulic containment of the tritium plume; and, 2) capturing/recovering tritium in groundwater. Data necessary to perform this evaluation include: 1) the routine monitoring of pumping rates and total effluent from the individual wells and within the temporary storage tank; 2) the evaluation of water levels in observation wells located adjacent to the extraction wells to demonstrate that groundwater extraction can hydraulically control the migration of the tritium in groundwater; and, 3) the periodic collection and analysis of groundwater samples from the extraction/observation wells and water samples from the temporary storage tank to demonstrate that through groundwater extraction, tritium concentrations are being reduced. The following sections provide the details of the data needs for the pilot study and groundwater extraction program, and the schedule and procedures for collecting and reporting the data.

4.2.1 Data Requirements

Data necessary to demonstrate the effectiveness of groundwater extraction for achieving the remedial goals are as follows:

- Effluent rates from the individual extraction wells and the overall system total effluent.
- Water-level measurements from the extraction wells and observation wells tracking the water level fluctuations during the pilot test.
- Analysis of groundwater quality samples obtained from the extraction wells, observation wells, and the storage tank for tritium.

From a mass balance perspective, the pumping rates and total effluent measurements will demonstrate that groundwater extraction can effectively remove recharge to groundwater in the area of Unit 1. Because the Station structures serve as an upgradient "no-flow" boundary for groundwater, recharge to groundwater is limited to recharge from precipitation. Assuming 10 inches of precipitation recharges to the shallow, water-bearing

unit every year, and considering the areal extent of groundwater containing tritium (approximately one acre), precipitation recharges to the aquifer at a rate of approximately 0.7 gpm. The effective pumping rate of the pilot study is anticipated to be approximately 2.5 gpm (18,000 gallons every five days), which is more than three times the assumed recharge to the shallow, water-bearing unit. The groundwater extraction system is anticipated to meet or exceed this pumping rate. If an effective pumping rate of 2.5 gpm can be maintained, then the pilot study will conservatively demonstrate the hydraulic containment of the plume from a mass balance perspective.

Water-level measurements obtained from the extraction and observation wells can offer a second line of evidence that groundwater extraction can hydraulically contain the further migration of tritium in groundwater. The water-level measurements will be evaluated to determine if extraction of water from additional locations is necessary to eliminate the hydraulic gradient that could result in the further migration of tritium or to target locations indicating relatively higher concentrations of tritium.

Groundwater quality data obtained from the extraction and observation wells and from the temporary storage tank will be evaluated to determine if groundwater extraction is effectively reducing the concentrations of tritium in the shallow, water-bearing unit. Tritium concentrations indicated by groundwater samples collected from monitoring wells associated with the pilot-study will likely fluctuate during its initial stages. These fluctuations will subsequently subside as the pilot study progresses.

4.2.2 Operations and Monitoring

The following sections present the details of the data that will be collected through the pilot-study to evaluate the effectiveness of groundwater extraction for achieving the objectives of the remedial action.

4.2.2.1 Pumping Rates

Flow rates for the individual extraction wells (initially consisting of Wells AB, AC, AD, and AI) will be obtained from in-line flow meters between the pumps and the temporary storage tank. The flow meter utilized during the pilot study will be able to accurately measure flow rates as low as 0.25 gpm. Flow rates for the individual extraction wells will be recorded periodically during each pumping cycle.

4.2.2.2 Total Effluent

The effluent volume for the individual wells will be recorded utilizing flow meters installed in line for the individual wells. Total effluent for the individual extraction wells will be

calculated based on each pumping cycle. In addition, the total accumulated volume of water in the storage tank will be recorded as part of the data collection.

4.2.2.3 Water-Level Measurements

Water-level measurements will initially be collected in the four extraction wells and select observation wells (currently Wells M, S, W, Y, Z, AA, AF, AG-Deep, AH-Deep, AJ, and AM) throughout the duration of the pilot-study. If deemed necessary, additional extraction/observation wells will be utilized. Data logging pressure transducers will be installed and maintained in the wells for data collection following the SOP outlined in Appendix C. Prior to the start of the test the pressure transducers will be checked and depth to water measured manually. Data from the pressure transducers will be downloaded and evaluated once a week for the first month of the pilot study then monthly thereafter. Similar to the pilot-study, data logging pressure transducers will be maintained in select wells during the implementation of the full-scale groundwater extraction system to monitor water levels.

4.2.2.4 Groundwater Quality

Groundwater monitoring will continue to be performed in accordance with the groundwater monitoring plan outlined in section 8 throughout the duration of the pilot study and the groundwater extraction program. In addition, characterization water samples from the storage tank will be collected prior to discharging the water in accordance with the Station's USNRC license. Groundwater samples and characterization samples will be analyzed for tritium and for gamma-emitting isotopes. Analytical results of the groundwater samples will be evaluated monthly to determine the effectiveness of groundwater extraction for reducing concentrations of tritium in groundwater. Select monitoring wells may also be analyzed for major cations and anions.

4.3 Full-Scale System Design and Implementation

Data obtained during the groundwater extraction pilot study will be evaluated to determine the effectiveness of the selected remedial alternative for achieving the remedial objectives. As outlined in Section 4.1, these objectives include: 1) the hydraulic containment of the tritium plume; and, 2) capturing/recovering tritium in groundwater. To demonstrate hydraulic containment of groundwater containing tritium, the groundwater extraction system must be able to sustain an effective pumping rate greater than the anticipated recharge rate to the shallow, water-bearing unit, and must be able to lower water levels within the tritium plume relative to water levels outside of the plume. To demonstrate the effectiveness of groundwater extraction for capturing/recovering tritium in groundwater, analytical results of groundwater samples collected from wells within the plume must indicate a decreasing trend for tritium over time.

The pilot study is being conducted to evaluate the ability of groundwater extraction to achieve the remedial objectives on a limited areal extent. Based on the evaluation of data obtained during the pilot study, the groundwater extraction system will be modified, as necessary. Modifications currently anticipated for the full-scale groundwater extraction system include the following:

1) The expansion of the pilot-study extraction well network to include other wells within the area of tritium exceeding the Further Action Criterion (this includes both existing well locations and/or well locations yet to be installed). The need for additional wells will be based on the ability of the pilot study network to lower water levels over the extent of the plume. The influence of the groundwater extraction system may not extend to the entire area indicating tritium concentrations above 20,000 pCi/L. If necessary, additional extraction wells will be utilized in these areas. Additionally, groundwater extraction wells will be considered for the area(s) of the plume anticipated to contain the highest concentrations of tritium, or where subsurface structures or interferences prevent efficient removal of the tritium with the existing well network. This will allow the for the flexibility of the full-scale system to continuously target the highest concentrations of tritium;

2) The expansion of the capacity of the groundwater extraction system. Currently, the groundwater extraction system has a capacity of 18,000 gallons. As detailed in section 4.2, the pilot-study schedule is anticipated to consist of the recovery of 18,000 gallons approximately every five days. The overall effective pumping rate for this schedule is 2.5 gpm;

3) The use of a mobile groundwater extraction unit for temporary/short term pumping at well locations not permanently plumbed to the full-scale system. This will allow for the flexibility to pump from alternate locations, as necessary; and,

4) Adjustments to the data collection schedule to support the full-scale system. This includes water level monitoring data, flow/pumping rates and groundwater monitoring. Once a history has been established and trends have been established, the need to collect this data on a more frequent basis will be reevaluated.

Based on a preliminary evaluation of data obtained during the pilot study, seven additional groundwater monitoring and/or extraction wells are proposed (Wells AN through AT). The locations of these wells are provided on **Figure 6**. The proposed wells will be constructed of nominal four inch Schedule 40 PVC. Wells AN and AO, located within the extent of the cofferdam, will be drilled to refusal. Wells AP, AQ, AR, AS, and AT will be terminated in the shallow, water-bearing unit above the clay, confining-unit.

Following completion of the pilot-study, and upon approval of this RAWP, PSEG will initiate the design, construction and operation of the full-scale groundwater extraction system. The ongoing groundwater remediation at the Station will be adaptively managed to routinely improve the performance of the full-scale groundwater extraction system. The full-scale design will allow for the flexibility to pump from all or only a limited number of wells within the extraction well network, which is anticipated to be expanded to include as many as 15 extraction wells. The use of a mobile groundwater extraction system will provide additional flexibility. The groundwater extraction system will be operated until PSEG can demonstrate that concentrations of tritium have been reduced to below the Further Action Criterion of 20,000 pCi/L. Upon completion of the remedial action, PSEG will prepare a Remedial Action Report that will include recommendations to: 1) decommission the groundwater extraction system; 2) to abandon the monitoring/extraction wells associated with this remedial action; and, 3) solicit the NJDEP to remove the Classification Exception Area and its obligations (see Section 6).

4.4 Remedial Action Progress

Pursuant to N.J.A.C. 7:26E-6.6, PSEG will prepare and submit Remedial Action Progress Reports (RAPR) periodically throughout the duration of the groundwater remediation. The initial RAPR will be submitted during the first full calendar quarter following approval of this RAWP and subsequent reports will be submitted during each calendar quarter for the first two years of operation of the groundwater extraction program. After this time, the reporting frequency will be reevaluated. Following the completion of the groundwater extraction pilot study the next scheduled progress report will include a detailed summary and evaluation of data collected throughout the pilot study. The RAPRs will provide the details of the full-scale remediation system design, the adaptive management measures employed during the reporting period, tritium analytical data, and any schedule changes for installation and operation of the system.

5 Well Search

In accordance with N.J.A.C. 7:26E-3.7, a well search was conducted to identify all monitoring wells within a one-half mile radius of Salem Unit 1, and all irrigation, industrial, public supply wells, and wells with water allocation permits within a one mile radius. PSEG Nuclear, LLC owns and/or controls all land within the one-half mile radius and maintains current records regarding the status of wells within this area. PSEG Nuclear, LLC reported that six public supply wells (PW-2, PW-3, PW-5, PW-6, HC-1, and HC-2) and three monitoring wells (OW-6, OW-G, and OW-J) are located within a one-half mile radius of Salem Unit 1. Additionally, one monitoring well (OW-1) is located on PSEG property beyond the one-half mile radius of Salem Unit 1 but within a one-mile radius. The locations and construction details of the wells maintained by PSEG Nuclear, LLC are identified on **Figure 7**.

6 Classification Exception Area

Pursuant to N.J.A.C. 7:9-6, in areas where groundwater contains constituents above GWQC, a Classification Exception Area (CEA) must be established to define the area. Site-related groundwater impacts are not expected to migrate beyond the property boundary at concentrations above applicable GWQC. Groundwater analytical data confirm that the current distribution of tritium is located entirely on site. As presented in Section 4, PSEG is currently proposing the use of groundwater extraction to prevent the further migration of tritium, and to reduce/recover tritium in groundwater. Additionally, a numerical model was prepared using MODFLOW to predict the fate and transport of tritium in groundwater based on known aquifer properties (e.g., hydraulic conductivity and gradient), and anticipated pumping scenarios. Based on the results of the groundwater modeling activities, which are presented in Appendix B, it is currently anticipated that the proposed full-scale groundwater extraction system will conservatively be in operation for approximately ten years.

The completed CEA/Well Restriction Area Fact Sheet is presented in **Appendix D**. The shallow water-bearing zone to which this CEA will be applied consists of the hydraulic fill, structural fill, and riverbed deposits of the shallow, water-bearing unit, which range in thickness from 20 to 45 feet. Pursuant to N.J.A.C. 7:9-6.5, groundwater in the area of the Site is presently designated as Class II-A. As presented in Section 2, constituents that have been identified in Site groundwater above New Jersey Class II-A ground water quality criteria (GWQC) are limited to tritium. In accordance with N.J.A.C. 7:26E-8.6, the proposed CEA duration and boundaries will be reevaluated and certified on a biennial basis.

7 Groundwater Monitoring Plan

A groundwater monitoring plan has been developed in support of the groundwater extraction pilot-study and for the full-scale implementation of the groundwater extraction program. The groundwater monitoring program defines the schedule for the periodic monitoring of groundwater quality. The groundwater monitoring plan consists of the schedule for the collection and laboratory analysis of groundwater samples from the monitoring well network, as well as the schedule for evaluating and submitting the results to the NJDEP-BNE. Based on the location, purpose, and analytical history of the monitoring wells within the network, the current monitoring wells have been segregated into groups to more effectively define their appropriate sampling schedule. The designated groups of monitoring wells consist of the Vincentown wells, the pilot-study groundwater extraction wells, the pilot-study observation wells, sentinel wells and other miscellaneous wells. The sampling schedule for the designated groups of monitoring wells consists of the following:

- **Vincentown Wells (Well K, Well L, Well P, Well Q, and Well V)** - Analytical results of groundwater samples collected from monitoring wells screened in the Vincentown Formation have consistently indicated concentrations of tritium either below the laboratory detection limits, or as is the case with Well K, consistently below the further investigation criterion (3,000 pCi/L). As such, the sampling frequency for these wells will be reduced from quarterly, as defined in the RIWP Addendum, to semi-annually.

- **Pilot-Study Groundwater Extraction Wells (Well AB, Well AC, Well AD, and Well AI)** –Groundwater samples will be collected from the pilot-study groundwater extraction wells on a weekly basis for the first month of the pilot-study. After the first month, the groundwater sampling frequency for these wells will be reduced to biweekly for month two and monthly thereafter.

- **Groundwater Extraction Program Pumping Wells** – Groundwater samples will be collected from the groundwater extraction wells on a weekly basis for the first month of pumping. After the first month, the groundwater sampling frequency for these wells will be reduced to biweekly for month two and monthly thereafter.

- **Pilot-Study Observation Wells (Well M, Well S, Well AA, Well AJ, and Well AM)** – Groundwater samples will be collected from select pilot-study observation wells on a biweekly basis for the first month of the pilot-study. After the first month, groundwater samples will be collected on a monthly basis.

- **Groundwater Extraction Program Observation Wells** – Groundwater samples will be collected from select observation wells on a weekly basis for the first month

following the implementation of the full-scale system, and will be collected monthly thereafter. The observation well network will be evaluated as part of the full-scale system design.

- **Sentinel Wells (Well Y, Well Z, Well AF, Wells AH Shallow and Deep, and Well AL)** – Groundwater samples will be collected from the sentinel wells, which monitor groundwater quality downgradient of the delineated extent of tritium in groundwater and upgradient of the property boundary, on a monthly basis.

- **Miscellaneous Wells (Well N, Well O, Well R, Well T, Well U, and Well AE)** –

  - Groundwater samples collected from Well N consistently indicate relatively low concentrations of tritium despite its location adjacent to the seismic gap. Initially, groundwater samples will be collected from this well on a monthly basis. If analytical results of groundwater samples collected from this well continue to indicate low concentrations of tritium following the initiation of the groundwater extraction pilot-study, then a reduction in sampling frequency will be considered.

  - Groundwater samples collected from Well R, which is located adjacent to the north side of the seismic gap, have consistently indicated concentrations of tritium at or below the further investigation criterion. Groundwater samples will continue to be collected from this well on a monthly basis; however, if groundwater samples collected from this well continue to indicate low concentrations of tritium, then a reduction in sampling frequency will be considered.

  - Groundwater samples recently collected from Well O indicated an increase in tritium concentrations. Well O will initially be monitored on a biweekly basis to reevaluate the analytical trend of groundwater samples collected from this well. After this period, sampling of Well O will be reduced to a monthly basis.

  - Analytical results of groundwater samples collected from Well AE are consistently above the further investigation criterion. Groundwater samples collected from Well AE will continue to be monitored on a monthly basis.

  - Groundwater samples collected from Well T and Well U, which are screened in the shallow, water-bearing unit north of the cofferdam, consistently indicate concentrations of tritium at or below the laboratory detection limit. As such, the sampling frequency for these monitoring wells will be reduced from quarterly to semi-annually.

- Currently, groundwater samples are collected from Wells AG Shallow and Deep on a biweekly basis. Based on groundwater analytical results for these wells, which indicate a high variability, groundwater samples will continue to be collected from these wells until analytical results stabilize.

Groundwater samples collected from the monitoring wells will be submitted to Salem Chemistry for a minimum of tritium and gamma-emitting isotope analysis. Groundwater samples indicating concentrations of tritium below or slightly above the detection limits of Salem Chemistry will be submitted to Maplewood Testing Services for analysis using more sensitive protocols. The sampling schedule and analysis described in this section provide a general guidance for obtaining data necessary to evaluate the effectiveness of the groundwater extraction system and to monitor the temporal distribution of tritium. Throughout the duration of the pilot-study and groundwater extraction program, groundwater samples may also be submitted for additional analyses (e.g., boron) and at a more frequent interval as described above.

Periodically, the sampling schedule will be revisited and modified to ensure the collection of data necessary to evaluate the progress of the groundwater extraction program. The modifications may include sampling frequency, sample analysis, and proposed well monitoring well network. These modifications will be presented in the RAPR.

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Table 01. 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.

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Table 02. 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
Beriun-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:

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Table 03. Field Parameter Measurements, PSEG Nuclear, LLC, Salem Generating Station, Hancock's Bridge, New Jersey.

Observation Well Identification	Date	Parameter					
		pH (SU)	Specific Conductance (mS/cm)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Temperature (°C)	Oxidation-Reduction Potential (mV)
Well K	02/04/04	6.71	8.11	12.6	0.13	14.18	222
Well L	03/23/04	9.20	0.67	48.8	0.37	12.87	-166
Well M	01/22/04	6.23	0.37	58.3	0.12	13.95	110
	02/17/04	7.24	0.35	17.3	0.13	12.48	25
	03/05/04	7.30	0.35	28.2	0.22	13.20	177
Well N	02/11/04	6.08	0.31	3.4	3.58	18.00	175
	03/18/04	5.89	0.31	38.0	2.81	20.05	221
Well O	01/14/04	6.45	1.19	7.9	0.76	13.06	81
	02/09/04	7.08	2.00	24.5	5.11	10.54	149
	03/03/04	6.52	2.34	12.6	0.36	13.26	124
	03/23/04	7.56	1.32	6.7	0.62	11.47	-131
Well P	01/22/04	6.13	12.08	3.5	0.09	12.80	156
Well Q	01/08/04	5.90	13.60	37.2	0.08	13.62	66
	02/04/04	6.08	13.95	6.2	0.17	14.52	105
	03/22/04	6.47	13.77	1.6	0.15	12.17	-23
Well R	01/22/04	6.19	0.60	23.4	0.09	12.24	94
	02/09/04	7.02	0.56	49.6	0.13	10.89	123
	03/05/04	7.23	0.53	49.4	0.17	12.64	198
Well S	02/17/04	7.06	0.54	12.1	0.10	13.97	-62
	03/18/04	6.01	0.56	12.4	0.14	14.20	265
Well T	03/22/04	7.02	6.30	40.4	0.12	14.74	1
Well U	03/22/04	6.80	1.21	25.5	0.12	13.54	4
Well V	03/22/04	7.16	4.31	15.1	0.21	12.35	-33
Well W	02/02/04	6.18	2.31	17.5	0.17	13.15	246
	03/03/04	9.38	1.63	11.8	0.40	14.60	137

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 03 - Field Parameters

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Table 03. Field Parameter Measurements, PSEG Nuclear, LLC, Salem Generating Station, Hancock's Bridge, New Jersey.

Observation Well Identification	Date	Parameter					
		pH (SU)	Specific Conductance (mS/cm)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Temperature (°C)	Oxidation-Reduction Potential (mV)
Well Y	01/06/04	6.50	7.55	7.5	0.08	13.77	-55
	02/02/04	6.57	7.77	8.13	0.06	13.9	6.4
	03/23/04	6.79	8.14	17	0.12	13.72	-35
Well Z	01/06/04	6.60	4.10	9.7	0.08	14.02	-85
	02/02/04	6.60	4.15	33.9	0.09	13.95	-32
	03/23/04	6.84	4.41	31.4	0.09	13.33	-38
Well AA	02/09/04	5.92	1.87	76.3	0.13	12.52	145
	03/18/04	6.03	1.79	109.0	0.21	12.43	152
Well AB	02/17/04	6.75	2.09	127.0	0.13	15.06	7
	03/03/04	6.39	2.11	40.1	0.07	16.62	159
Well AC	02/18/04	6.80	0.37	30.4	0.14	17.59	103
	03/18/04	6.00	0.41	13.0	0.14	18.04	268
Well AD	02/17/04	6.99	1.04	30.2	0.10	14.44	-20
	03/03/04	6.98	1.07	13.1	0.21	15.70	19
Well AE	02/09/04	6.79	0.21	23.1	2.02	12.62	118
	03/03/04	6.86	0.25	5.6	1.23	14.88	188
	03/18/04	5.40	0.25	7.5	0.11	12.84	403
Well AF	01/06/04	6.50	3.96	3.3	0.05	16.70	-101
	01/20/04	6.44	4.01	4.0	0.06	15.57	223
Well AF	02/02/04	6.54	4.46	0.0	0.05	17.10	-48
	03/18/04	6.86	5.10	12.5	0.24	16.00	-8
AG-Shallow	02/23/04	12.94	5.54	5.5	0.12	13.40	119
	03/09/04	11.70	4.18	6.9	0.34	12.57	89
	03/29/04	12.70	3.39	10.2	0.10	13.27	-6
AG-Deep	02/23/04	8.17	6.08	23.9	0.21	11.56	88
	03/09/04	8.12	5.35	11.5	0.10	13.26	118
	03/29/04	8.25	5.56	16.3	0.43	14.67	99
AH-Shallow	02/23/04	10.35	1.33	7.6	0.68	14.13	150
	03/08/04	10.27	0.90	4.1	1.43	13.05	225
	03/29/04	10.56	0.63	19.9	0.15	13.74	-142

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

Observation Well Identification	Date	Parameter					
		pH (SU)	Specific Conductance (mS/cm)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Temperature (°C)	Oxidation-Reduction Potential (mV)
AH-Deep	02/23/04	7.23	2.70	17.6	0.10	16.01	-97
	03/08/04	6.39	2.48	5.2	0.19	15.18	332
	03/29/04	8.42	2.72	62.1	0.09	14.97	-21
AI	02/26/04	5.77	0.22	36.2	0.22	13.95	355
	03/11/04	7.52	0.23	27.8	0.34	14.86	28
	03/30/04	7.12	0.23	22.9	0.16	14.55	20
AJ	02/25/04	6.77	4.26	141.0	0.20	16.80	44
	03/09/04	6.48	4.34	110.0	0.10	17.23	92
	03/30/04	6.91	4.21	98.0	0.16	16.93	83
AL	02/25/04	6.13	0.44	14.6	0.12	14.57	345
	03/09/04	6.38	0.50	18.1	0.08	15.23	74
	03/30/04	7.44	0.49	14.8	0.75	15.01	40
AM	02/26/04	7.01	0.26	25.4	4.16	15.99	209
	03/11/04	6.66	0.25	16.3	0.96	17.24	295
Maximum Measurement		12.94	13.95	141.0	5.11	20.05	403
Minimum Measurement		5.40	0.21	0.0	0.05	10.54	-166
Average Measurement		7.21	3.05	27.3	0.48	14.31	89
Standard Deviation		1.53	3.41	29.9	0.95	1.84	125.8

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

Well Identification	Sample Date	Tritium			Major Cations and Anions	
		Result (pCi/L)	Deviation (pCi/L)	LLD (pCi/L)	Boron (ug/L)	Sodium (mg/L)
K	02/04/04	762	94.6	139	--	--
L	05/04/04	<138	82.1	138	--	--
L	05/10/04	<138	83.9	138	--	--
L[1]	05/19/04	<5,780	NA	NA	--	--
L[1]	05/24/04	<4,560	NA	NA	--	--
M	01/22/04	7,340	164	140	--	--
M[2]	02/17/04	11,300	NA	NA	--	--
M	03/05/04	7,170	168	146	150	22
M	04/29/04	6,510	159	141	120	21
M	05/11/04	2,350	117	141	--	--
N	02/11/04	5,950	154	139	--	--
N	03/18/04	6,550	162	145	--	--
N	04/08/04	7,180	164	137	230	17
N[2]	05/12/04	10,200	NA	NA	<3,330	19.4
N[2]	06/03/04	9,760	NA	NA	--	--
O	01/14/04	3,750	132	141	300	1,850
O[2]	02/09/04	24,200	NA	NA	--	--
O[2]	03/03/04	21,800	NA	NA	283	1,720
O[2]	03/23/04	21,000	NA	NA	--	--
O	04/06/04	19,300	247	136	281	120.0
O	05/03/04	20,400	253	140	--	--
O	05/11/04	20,700	254	140	--	--

Notes:

ug/L	Micrograms per liter
mg/L	Milligrams per liter
pCi/L	Picocuries per liter
1	Reported analytical results are from Salem Chemistry. Analytical results from Maplewood are pending.
2	Reported analytical results are from Salem Chemistry. Groundwater samples were not submitted to Maplewood for additional analysis.
<141	Constituent was not detected above the laboratory detection limit.
762	Constituent was detected above the laboratory method detection limit.
1,250,000	Constituent was detected above its New Jersey Groundwater Quality Criteria.
NA	Not Available - Deviation and LLD for Salem Chemistry are not reported.
--	Constituent not analyzed.

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Table 04. Recent Groundwater Analytical Results, PSEG Nuclear, LLC, Salem Generating Station, Hancock's Bridge, New Jersey.

Well Identification	Sample Date	Tritium			Major Cations and Anions	
		Result (pCi/L)	Deviation (pCi/L)	LLD (pCi/L)	Boron (ug/L)	Sodium (mg/L)
P	01/22/04	<144	85.5	144	--	--
P	04/28/04	<139	83.2	139	441	1,550
Q	01/08/04	<142	83.1	142	300	1,850
Q	02/04/04	<139	83.5	139	--	--
Q	03/22/04	<144	85.4	144	283	1,720
Q[1]	06/04/04	<4,560	NA	NA	--	--
R	01/22/04	2,210	116	143	--	--
R	02/09/04	2,230	115	140	--	--
R	03/05/04	2,200	117	146	--	--
R[2]	04/28/04	<5,780	NA	NA	265	41.6
R[2]	05/24/04	4,800	NA	NA	--	--
S[2]	01/20/04	1,420,000	NA	NA	--	--
S[2]	02/17/04	1,250,000	NA	NA	--	--
S[2]	03/18/04	1,220,000	NA	NA	--	--
S[2]	04/06/04	1,160,000	NA	NA	--	--
S[2]	05/04/04	1,100,000	NA	NA	44,500	34.6
S[2]	05/19/04	889,000	NA	NA	--	--
T	03/22/04	<142	84.0	142	649	986
T	04/12/04	<141	84.1	141	762	920
U	03/22/04	<144	87.5	144	379	168
U	04/12/04	182	84.2	136	392	146

Notes:

ug/L	Micrograms per liter
mg/L	Milligrams per liter
pCi/L	Picocuries per liter
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NA	Not Available - Deviation and LLD for Salem Chemistry are not reported.
--	Constituent not analyzed.

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Table 04. Recent Groundwater Analytical Results, PSEG Nuclear, LLC, Salem Generating Station, Hancock's Bridge, New Jersey.

Well Identification	Sample Date	Tritium			Major Cations and Anions	
		Result (pCi/L)	Deviation (pCi/L)	LLD (pCi/L)	Boron (ug/L)	Sodium (mg/L)
V	03/22/04	290	90.2	144	456	556
V	04/12/04	316	86.9	137	529	567
W	01/14/04	17,100	232	144	--	--
W	02/02/04	19,600	251	144	--	--
W	03/03/04	7,060	151	146	280	273
W	04/29/04	4,570	140	140	140	212
W	05/10/04	2,350	117	141	--	--
W[1]	05/24/04	6,610	NA	NA	--	--
Y	01/06/04	<142	84.7	142	--	--
Y	02/02/04	<145	86.5	145	--	--
Y	03/23/04	<145	86.0	145	--	--
Y	04/07/04	<136	81.9	136	830	1,080
Y	05/10/04	<143	84.7	143	--	--
Z	01/06/04	648	94.5	142	--	--
Z	02/02/04	538	94.7	145	--	--
Z	03/23/04	412	92.1	144	--	--
Z	04/07/04	580	91.2	137	50	531
Z	05/10/04	561	93.3	142	--	--
AA	01/06/04	713	95.1	141	--	--
AA	02/09/04	1,130	99.9	139	--	--
AA	03/18/04	2,610	120	140	--	--
AA	04/12/04	3,140	126	140	240	169
AA[1]	05/03/04	<5,590	NA	NA	--	--
AA[1]	05/19/04	<3,320	NA	NA	--	--

Notes:

ug/L	Micrograms per liter
mg/L	Milligrams per liter
pCi/L	Picocuries per liter
[1]	Reported analytical results are from Salem Chemistry. Analytical results from Maplewood are pending.
<141	Constituent was not detected above the laboratory detection limit.
762	Constituent was detected above the laboratory method detection limit.
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--	Constituent not analyzed.

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Table 04. Recent Groundwater Analytical Results, PSEG Nuclear, LLC, Salem Generating Station, Hancock's Bridge, New Jersey.

Well Identification	Sample Date	Tritium			Major Cations and Anions	
		Result (pCi/L)	Deviation (pCi/L)	LLD (pCi/L)	Boron (ug/L)	Sodium (mg/L)
AB[2]	01/14/04	281,000	NA	NA	--	--
AB[2]	02/17/04	215,000	NA	NA	--	--
AB[2]	03/03/04	193,000	NA	NA	--	--
AB[2]	04/06/04	260,000	NA	NA	--	--
AB[2]	05/04/04	136,000	NA	NA	9,300	134
AB[2]	05/11/04	144,000	NA	NA	--	--
AB[2]	05/19/04	172,000	NA	NA	<3,330	292
AB[2]	05/24/04	213,000	NA	NA	--	--
AB[2]	06/03/04	210,000	NA	NA	<3,330	105
AC[2]	01/20/04	10,700,000	NA	NA	--	--
AC[2]	02/18/04	9,170,000	NA	NA	--	--
AC[2]	03/18/04	6,360,000	NA	NA	--	--
AC[2]	04/08/04	6,560,000	NA	NA	--	--
AC[2]	06/04/04	3,400,000	NA	NA	<3,330	12.0
AD[2]	01/14/04	220,000	NA	NA	--	--
AD[2]	02/17/04	400,000	NA	NA	--	--
AD[2]	03/03/04	420,000	NA	NA	--	--
AD[2]	04/06/04	542,000	NA	NA	--	--
AD[2]	05/04/04	624,000	NA	NA	5,800	65
AD[2]	05/11/04	599,000	NA	NA	--	--
AD[2]	05/19/04	610,000	NA	NA	<3,330	109
AD[2]	06/03/04	744,000	NA	NA	<3,330	70.8

Notes:

ug/L	Micrograms per liter
mg/L	Milligrams per liter
pCi/L	Picocuries per liter
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Table 04. Recent Groundwater Analytical Results, PSEG Nuclear, LLC, Salem Generating Station, Hancock's Bridge, New Jersey.

Well Identification	Sample Date	Tritium			Major Cations and Anions	
		Result (pCi/L)	Deviation (pCi/L)	LLD (pCi/L)	Boron (ug/L)	Sodium (mg/L)
AE	01/14/04	16,100	229	144	--	--
AE	02/09/04	16,600	232	139	--	--
AE	03/03/04	17,000	237	147	--	--
AE	03/18/04	19,000	248	145	--	--
AE	04/28/04	14,900	220	140	90	8
AE[1]	05/03/04	14,000	NA	NA	--	--
AF	01/06/04	366	90.2	142	--	--
AF	01/20/04	262	89.3	143	--	--
AF	02/02/04	295	90.6	144	--	--
AF	03/18/04	150	88.0	144	--	--
AF	04/20/04	247	87.8	141	480	654
AF	05/03/04	308	88.6	141	--	--
AG-Shallow	02/23/04	2,320	115	138	40	348
AG-Shallow	03/09/04	2,996	126	146	--	--
AG-Shallow	03/29/04	4,810	150	153	--	--
AG-Shallow	04/12/04	6,620	161	143	260	319
AG-Shallow	04/20/04	8,060	173	142	230	338
AG-Shallow	04/28/04	10,300	188	136	190	312
AG-Shallow	05/10/04	9,580	184	139	--	--
AG-Shallow[2]	05/24/04	10,400	NA	NA	--	--
AG-Shallow[2]	05/26/04	11,300	NA	NA	--	--
AG-Shallow[2]	05/27/04	18,300	NA	NA	--	--
AG-Shallow[2]	05/28/04	14,400	NA	NA	--	--
AG-Shallow[2]	06/03/04	25,400	NA	NA	--	--
AG-Shallow[2]	06/08/04	10,800	NA	NA	--	--

Notes:

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Table 04. Recent Groundwater Analytical Results, PSEG Nuclear, LLC, Salem Generating Station, Hancock's Bridge, New Jersey.

Well Identification	Sample Date	Tritium			Major Cations and Anions	
		Result (pCi/L)	Deviation (pCi/L)	LLD (pCi/L)	Boron (ug/L)	Sodium (mg/L)
AG-Deep	02/23/04	6,100	156	140	340	849
AG-Deep	03/09/04	3,277	132	149	--	--
AG-Deep	03/29/04	2,540	125	151	--	--
AG-Deep	04/12/04	4,990	145	141	510	765
AG-Deep	04/19/04	2,920	124	141	500	868
AG-Deep	04/28/04	896	94.5	135	380	866
AG-Deep[2]	05/03/04	<5,590	NA	NA	--	--
AG-Deep	05/10/04	1,490	106	140	--	--
AG-Deep[2]	05/24/04	<4,560	NA	NA	--	--
AG-Deep[2]	05/28/04	<4,560	NA	NA	--	--
AG-Deep[2]	06/03/04	6,010	NA	NA	--	--
AG-Deep[2]	06/08/04	13,700	NA	NA	--	--
AH-Shallow	02/23/04	899	98.8	143	140	135
AH-Shallow	03/08/04	894	98.2	142	--	--
AH-Shallow	03/29/04	878	97.3	141	--	--
AH-Shallow	04/20/04	932	98.4	141	250	67
AH-Shallow	05/03/04	908	98.0	141	--	--
AH-Shallow[1]	06/03/04	<4,560	NA	NA	--	--
AH-Deep	02/23/04	548	93.3	142	210	309
AH-Deep	03/08/04	620	94.7	142	--	--
AH-Deep	03/29/04	522	92.8	142	--	--
AH-Deep	04/19/04	563	92.5	140	190	241
AH-Deep	05/03/04	637	94.6	142	--	--
AH-Deep[1]	06/03/04	<4,560	NA	NA	--	--

Notes:

ug/L	Micrograms per liter
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pCi/L	Picocuries per liter
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Table 04. Recent Groundwater Analytical Results, PSEG Nuclear, LLC, Salem Generating Station, Hancock's Bridge, New Jersey.

Well Identification	Sample Date	Tritium			Major Cations and Anions	
		Result (pCi/L)	Deviation (pCi/L)	LLD (pCi/L)	Boron (ug/L)	Sodium (mg/L)
AI[2]	02/02/04	<5,780	NA	NA	--	--
AI	02/26/04	4,360	138	140	50	8
AI	03/11/04	4,370	141	145	--	--
AI	03/30/04	3,550	131	143	--	--
AI	05/04/04	11,800	200	140	--	--
AI[2]	05/11/04	40,800	NA	NA	--	--
AI[2]	05/19/04	44,100	NA	NA	<3,330	47
AI[2]	06/03/04	45,900	NA	NA	--	--
AJ	02/25/04	1,150	102	142	620	616
AJ	03/09/04	1,040	99.1	140	680	650
AJ	03/30/04	1,080	103	146	620	642
AJ	04/19/04	1,190	101	139	670	621
AJ	05/10/04	1,240	103	142	--	--
AJ[1]	05/24/04	<4,560	NA	NA	--	--
AL	02/25/04	<141	83.3	141	210	60
AL	03/09/04	<147	86.1	147	--	--
AL	03/30/04	<146	85.8	146	220	63
AL	04/19/04	<141	85.3	141	300	62
AL[1]	05/19/04	<5,780	NA	NA	--	--
AM[2]	02/26/04	273,000	NA	NA	--	--
AM[2]	03/11/04	234,000	NA	NA	--	--
AM[2]	04/08/04	196,000	NA	NA	--	--
AM[2]	05/06/04	150,000	NA	NA	--	--
AM[2]	05/20/04	149,000	NA	NA	<3,330	6

Notes:

ug/L	Micrograms per liter
mg/L	Milligrams per liter
pCi/L	Picocuries per liter
1	Reported analytical results are from Salem Chemistry. Analytical results from Maplewood are pending.
2	Reported analytical results are from Salem Chemistry. Groundwater samples were not submitted to Maplewood for additional analysis.
<141	Constituent was not detected above the laboratory detection limit.
762	Constituent was detected above the laboratory method detection limit.
1,250,000	Constituent was detected above its New Jersey Groundwater Quality Criteria.
NA	Not Available - Deviation and LLD for Salem Chemistry are not reported.
--	Constituent not analyzed.

Table 05. 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
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
		Well N	94.33	4.41	93.55	3.63	93.73	3.81	93.00
		Well O	95.17	5.25	94.50	4.58	94.79	4.87	93.45
		Well R	96.50	6.58	95.86	5.94	96.04	6.12	94.44
		Well AC	--	--	--	--	--	--	93.01
		Well AE	--	--	--	--	--	--	93.15
		Well AI	--	--	--	--	--	--	--
		Well AM	--	--	--	--	--	--	--
		Mean	95.28	5.36	94.62	4.70	94.83	4.91	93.44
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
		Well T	92.95	3.03	92.66	2.74	92.62	2.70	92.74
		Well U	93.20	3.28	92.85	2.93	92.82	2.90	92.79
		Well W	92.86	2.94	92.41	2.49	92.41	2.49	92.29
		Well Y	--	--	--	--	--	--	92.09
		Well Z	--	--	--	--	--	--	92.07
		Well AA	--	--	--	--	--	--	91.97
		Well AB	--	--	--	--	--	--	92.31
		Well AD	--	--	--	--	--	--	92.17
		Well AF	--	--	--	--	--	--	92.18
		Well AG (Shallow)	--	--	--	--	--	--	--
		Well AG (Deep)	--	--	--	--	--	--	--
		Well AH (Shallow)	--	--	--	--	--	--	--
		Well AH (Deep)	--	--	--	--	--	--	--
		Well AJ	--	--	--	--	--	--	--
		Well AL	--	--	--	--	--	--	--
		Mean	92.99	3.07	92.60	2.68	92.60	2.68	92.31
70 to 80	Vincentown Formation	Well K	91.36	1.44	90.98	1.06	90.84	0.92	91.90
		Well L	91.35	1.43	90.61	0.69	90.54	0.62	92.42
		Well P	91.32	1.40	90.67	0.75	90.37	0.45	92.55
		Well Q	91.29	1.37	89.90	-0.02	91.08	1.16	91.51
		Well V	91.58	1.66	91.08	1.16	90.92	1.00	92.00
		Mean	91.38	1.46	90.65	0.73	90.75	0.83	92.08

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).

Table 05. Groundwater Elevations, PSEG Salem Generating Station, I

Screened Interval - Typical (ft bgs)	Monitored Lithologic Unit[1]	Well Identification	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	Water-Level Elevation (ft rpd) 19-Mar-2004	Water-Level Elevation (ft amsl) 19-Mar-2004
10 to 20	Shallow, Water-Bearing Unit (Inside the Limits of Cofferdam)	Well M	3.66	93.37	3.45	93.51	3.59	93.64	3.72
		Well N	3.08	92.76	2.84	92.29	2.37	92.35	2.43
		Well O	3.53	93.57	3.65	92.47	2.55	94.41	4.49
		Well R	4.52	94.65	4.73	94.84	4.92	NM	NM
		Well AC	3.09	92.82	2.90	NM	NM	93.56	3.64
		Well AE	3.23	94.32	4.40	92.13	2.21	94.43	4.51
		Well AI	--	--	--	92.21	2.29	92.29	2.37
		Well AM	--	--	--	92.30	2.38	92.73	2.81
		Mean	3.52	93.58	3.66	92.82	2.90	93.34	3.42
25 to 35	Shallow, Water-Bearing Unit (Outside the Limits of Cofferdam)	Well S	2.52	92.10	2.18	91.57	1.65	91.72	1.80
		Well T	2.82	92.06	2.14	91.76	1.84	91.73	1.81
		Well U	2.87	92.14	2.22	91.87	1.95	91.99	2.07
		Well W	2.37	91.79	1.87	91.41	1.49	91.82	1.90
		Well Y	2.17	91.68	1.76	91.19	1.27	91.19	1.27
		Well Z	2.15	91.70	1.78	91.13	1.21	91.24	1.32
		Well AA	2.05	91.57	1.65	91.08	1.16	91.19	1.27
		Well AB	2.39	92.03	2.11	91.53	1.61	91.79	1.87
		Well AD	2.25	91.80	1.88	91.24	1.32	91.48	1.56
		Well AF	2.26	91.80	1.88	91.23	1.31	91.59	1.67
		Well AG (Shallow)	--	--	--	90.92	1.00	91.09	1.17
		Well AG (Deep)	--	--	--	90.85	0.93	90.30	0.38
		Well AH (Shallow)	--	--	--	90.45	0.53	90.91	0.99
		Well AH (Deep)	--	--	--	90.71	0.79	91.14	1.22
		Well AJ	--	--	--	91.40	1.48	91.63	1.71
		Well AL	--	--	--	93.11	3.19	93.71	3.79
		Mean	2.39	91.87	1.95	91.34	1.42	91.53	1.61
70 to 80	Vincentown Formation	Well K	1.98	90.12	0.20	NM	NM	91.20	1.28
		Well L	2.50	91.91	1.99	NM	NM	90.85	0.93
		Well P	2.63	93.23	3.31	NM	NM	92.07	2.15
		Well Q	1.59	91.18	1.26	NM	NM	90.81	0.89
		Well V	2.08	91.32	1.40	NM	NM	91.33	1.41
		Mean	2.16	91.55	1.63	NM	NM	91.25	1.33

Notes

[1] Lithologic units correspond with those outlined riverbed deposits. The shallow, water-bearing

-- Monitoring well not installed at the time of the

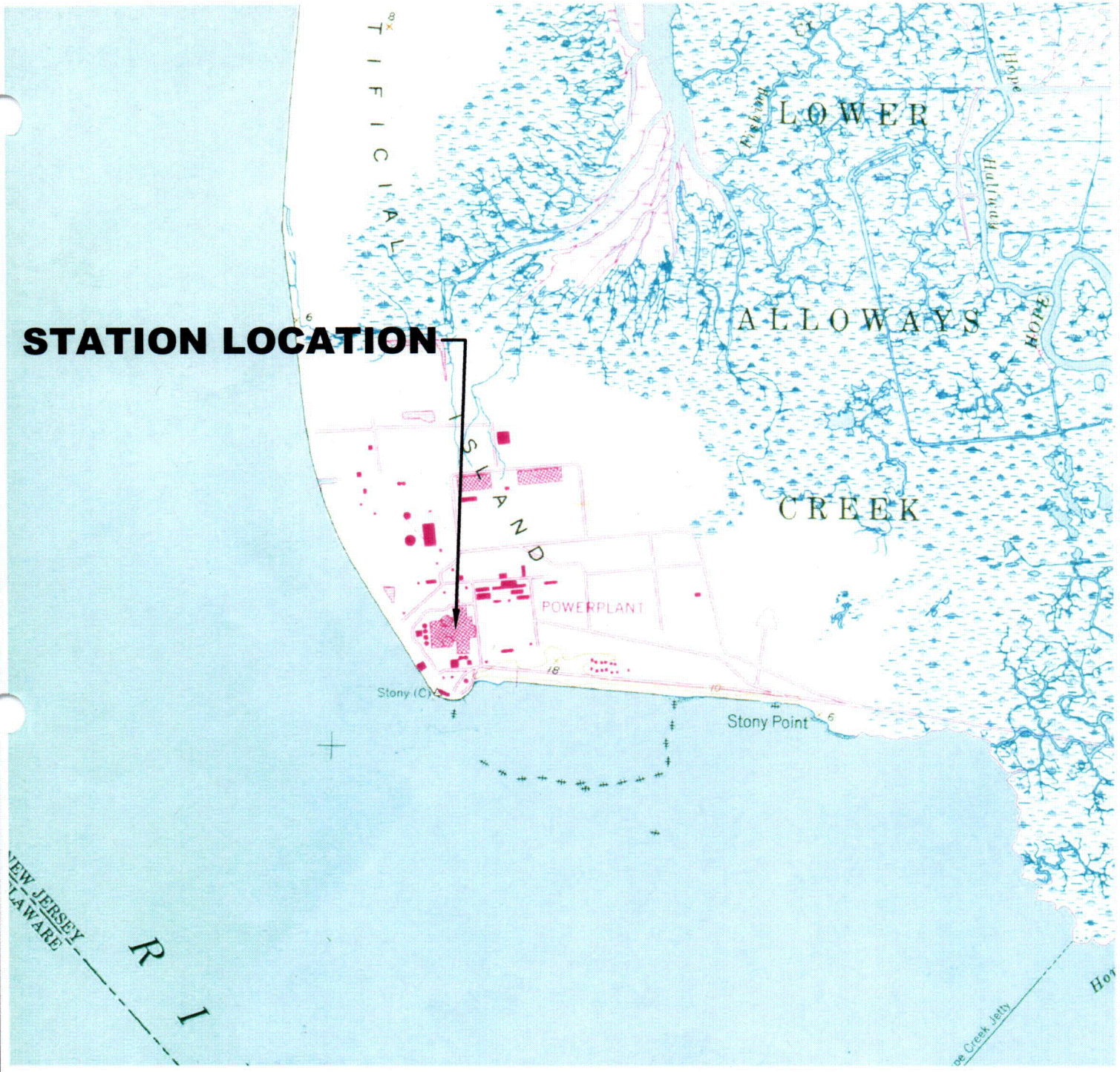
NM Water level measurement not collected.

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



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1 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

MN GN
10 ½° 187 MILS
0°21' 6 MIL

UTM GRID AND 1981 MAGNETIC NORTH

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

ARCADIS

DRAWN	DATE	PROJECT MANAGER	DEPARTMENT MANAGER
M. WASILEWSKI	4/26/04	P. MILIONIS	D. FULTON
		LEAD DESIGN PROF. S. POTTER	CHECKED B. PIERCE
		PROJECT NUMBER NP000571.0004	DRAWING NUMBER 1

STATION LOCATION

PSEG NUCLEAR, LLC
SALEM GENERATING STATION
ARTIFICIAL ISLAND
HANCOCK'S BRIDGE, NEW JERSEY

G:\APROJECT\PSE&G\Salem\NP000571.0004 – Remedial Actions\Task 04 – RAWP\cadd\FIG-1 STATION LOCATION.DWG 7/13/2004 – 4:39:08 PM Layout: 8.5x11 H

C01B

THIS PAGE IS AN OVERSIZED DRAWING OR FIGURE,

THAT CAN BE VIEWED AT THE RECORD TITLED:

"STATION LAYOUT"

WITHIN THIS PACKAGE..

D-01

THIS PAGE IS AN OVERSIZED DRAWING OR FIGURE,

THAT CAN BE VIEWED AT THE RECORD TITLED:

"MONITORING WELL NETWORK"

WITHIN THIS PACKAGE..

D-02

THIS PAGE IS AN OVERSIZED DRAWING OR FIGURE,

THAT CAN BE VIEWED AT THE RECORD TITLED:

"GROUNDWATER ELEVATION COUNTOURS SHALLOW WATER - BEARING UNIT".

WITHIN THIS PACKAGE..

D-03

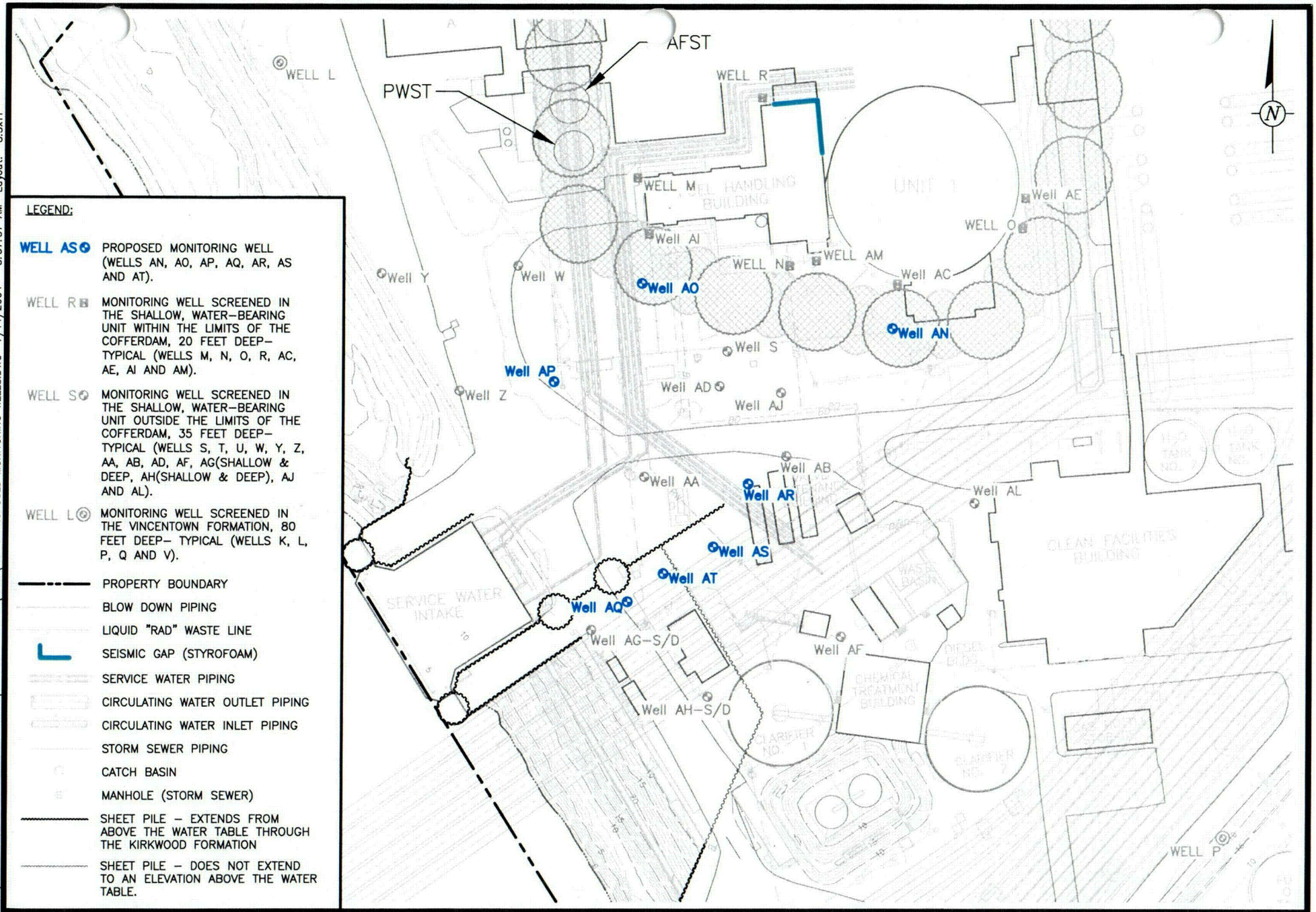
THIS PAGE IS AN OVERSIZED DRAWING OR FIGURE,

THAT CAN BE VIEWED AT THE RECORD TITLED:

"GROUNDWATER TRITIUM RESULTS".

WITHIN THIS PACKAGE..

D-04



LEGEND:

- **WELL AS** — PROPOSED MONITORING WELL (WELLS AN, AO, AP, AQ, AR, AS AND AT).
- WELL R — MONITORING WELL SCREENED IN THE SHALLOW, WATER-BEARING UNIT WITHIN THE LIMITS OF THE COFFERDAM, 20 FEET DEEP- TYPICAL (WELLS M, N, O, R, AC, AE, AI AND AM).
- WELL S — MONITORING WELL SCREENED IN THE SHALLOW, WATER-BEARING UNIT OUTSIDE THE LIMITS OF THE COFFERDAM, 35 FEET DEEP- TYPICAL (WELLS S, T, U, W, Y, Z, AA, AB, AD, AF, AG(SHALLOW & DEEP, AH(SHALLOW & DEEP), AJ AND AL).
- WELL L — MONITORING WELL SCREENED IN THE VINCENTOWN FORMATION, 80 FEET DEEP- TYPICAL (WELLS K, L, P, Q AND V).
- PROPERTY BOUNDARY
- BLOW DOWN PIPING
- LIQUID "RAD" WASTE LINE
- SEISMIC GAP (STYROFOAM)
- SERVICE WATER PIPING
- CIRCULATING WATER OUTLET PIPING
- CIRCULATING WATER INLET PIPING
- STORM SEWER PIPING
- CATCH BASIN
- MANHOLE (STORM SEWER)
- SHEET PILE - EXTENDS FROM ABOVE THE WATER TABLE THROUGH THE KIRKWOOD FORMATION
- SHEET PILE - DOES NOT EXTEND TO AN ELEVATION ABOVE THE WATER TABLE.

0 100
SCALE: 1"=100'

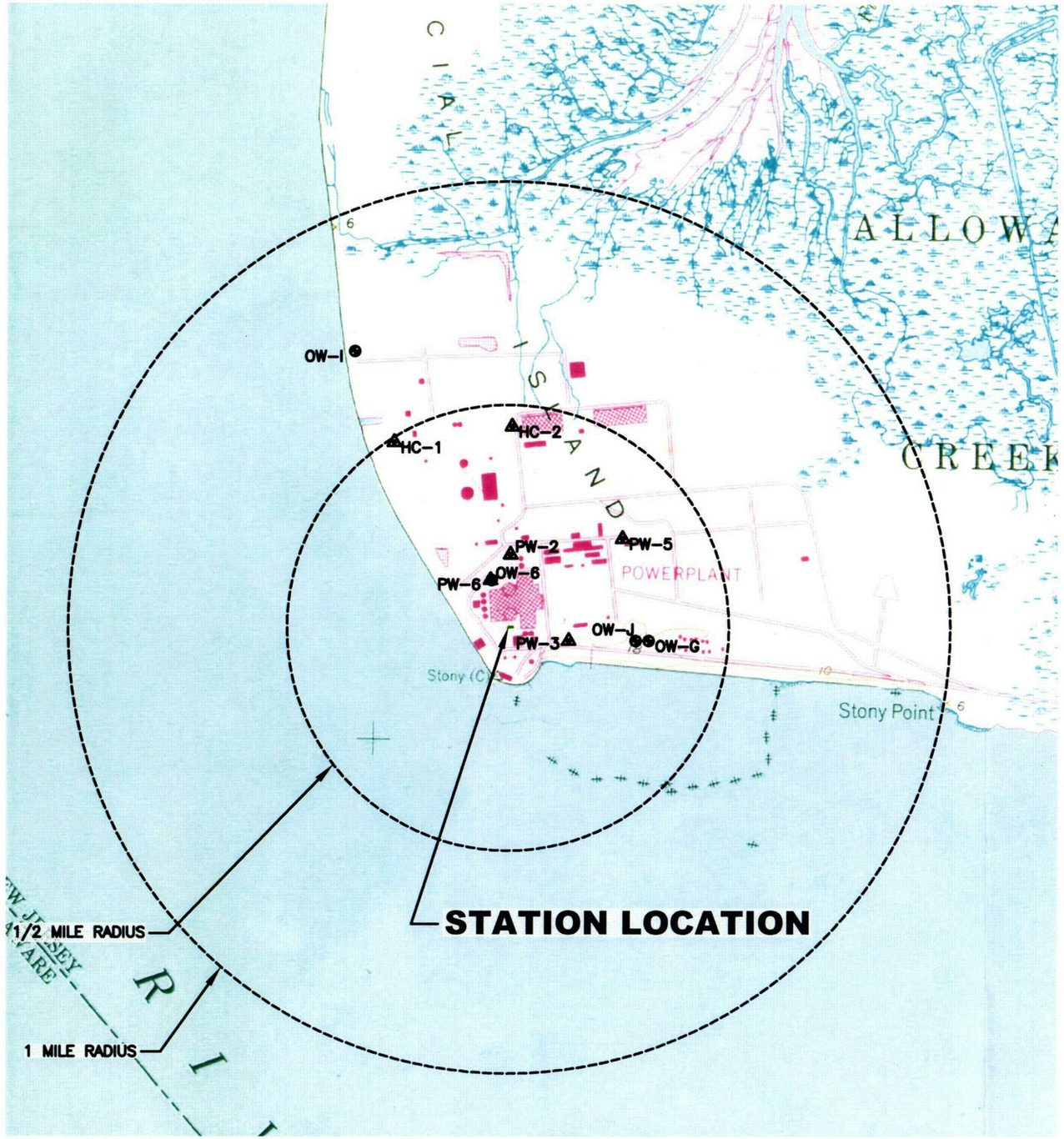
ARCADIS

DRAWN	DATE	PROJECT MANAGER	DEPARTMENT MANAGER
M. WASILEWSKI	5/5/04	P. MILIONIS	D. FULTON
		LEAD DESIGN PROF. S. POTTER	CHECKED B. PIERCE
		PROJECT NUMBER NP000571.0004	DRAWING NUMBER 6

PROPOSED ADDITIONAL MONITORING WELLS

PSEG NUCLEAR, LLC
SALEM GENERATING STATION
ARTIFICIAL ISLAND
HANCOCK'S BRIDGE, NEW JERSEY

G:\APROJECT\PSE&G\Salem\NP000571.0004 - Remedial Actions\Task 04 - RAWP\cadd\FIG-6 PROPOSED MONITORING WELLS.DWG 7/14/2004 - 8:57:37 AM Layout: 8.5x11



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

Details of Wells Maintained by PSEG Nuclear, LLC Within a One-Mile Radius of Salem Unit 1.

Well ID	Well Permit No.	Use	Total Depth (feet bgs)	Static Water Depth (feet bgs)	Monitored Hydrogeologic Unit [1]	Latitude	Longitude
PW-2	3400757	Public, Non-Community	281	18	Mt. Laurel/Wenonah	39°27'53"	75°32'08"
PW-3	3400758	Public, Non-Community	293	21	Mt. Laurel/Wenonah	39°27'43"	75°31'59"
PW-5	3401031	Public, Non-Community	840	35	Middle Raritan	39°27'55"	75°31'51"
PW-6	3401512	Public, Non-Community	1135	46	Lower Raritan	39°27'50"	75°32'11"
HC-1	3401073	Public, Non-Community	816	83	Middle Raritan	39°28'06"	75°32'26"
HC-2	3401074	Public, Non-Community	815	79	Middle Raritan	39°28'08"	75°32'08"
OW-6	3401511	Monitoring	1132	NA	Lower Raritan	39°27'50"	75°32'11"
OW-G	3400970	Monitoring	311	NA	Mt. Laurel/Wenonah	39°27'43"	75°31'47"
OW-I	3401011	Monitoring	790	NA	Middle Raritan	39°28'22"	75°32'32"
OW-J	3404055	Monitoring	840	NA	Middle Raritan	39°27'43"	75°31'49"

Notes:

NA – Information is not available.

[1] – Monitored hydrogeologic units correspond to those described in the April 2004 Remedial Investigation Report.

LEGEND:

OW–J● MONITORING WELL LOCATION (OW–6, OW–G, OW–1 AND OW–J)

PW–3▲ PRODUCTION WELL LOCATION (PW–2, PW–3, PW–5, PW–6, HC–1 AND HC–2)

QUADRANGLE LOCATION

0 1,500
SCALE: 1"=1,500'

NO.	DATE	REVISION DESCRIPTION	BY	CKD

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	DATE	PROJECT MANAGER	DEPARTMENT MANAGER
M. WASILEWSKI	4/26/04	P. MILIONIS	D. FULTON
		LEAD DESIGN PROF. S. POTTER	CHECKED B. PIERCE
		PROJECT NUMBER	DRAWING NUMBER
		NP000571.0004	7

WELL SEARCH RESULTS

C03

Appendix A

Iodine-129 Analysis

Summary

To investigate the potential sources of tritium contamination in groundwater wells at Salem, we extend the use of radioactive tracers to include the long-lived radioactive isotope of iodine, ^{129}I (15.7 million year half life). Iodine and tritium behave as "conservative" (non-reactive) tracers in groundwater in the absence of high concentrations of organic matter. Our goal is to use the ratio and absolute concentration of the two tracers to differentiate among possible sources of tritium at Salem. This methodology has been previously used to investigate elevated tritium levels at Ginna Power Station, NY. Large quantities of iodine-129 have been released dominantly from fuel reprocessing plants, including West Valley, NY. Because of the continued releases of ^{129}I from reprocessing, anthropogenic ^{129}I additions have swamped the natural budget, resulting in elevated $^{129}I/I$ ratios in surface waters worldwide. Even with this increased background, localized releases of water containing elevated levels of ^{129}I (e.g. Spent Fuel Pool water or fuel reprocessing activity) can be observed over the background signal. The ^{129}I analysis was performed to evaluate if tritium detected in groundwater is the result of a release of water from the Spent Fuel Pool, which contains relatively high levels of ^{129}I (10^{11} atoms/g), and if the release of Spent Fuel Pool water has migrated to the Vincentown Formation.

Groundwater Wells from Salem contain elevated levels of I-129 that are typical for waters in the northeastern US. There is no evidence of any addition of an I-129 rich component from the Spent fuel Pool. Three samples are "pre-nuclear" based on the low to "non-detect" levels of tritium (see Figure 1and 2). Well Q (at 80 feet) has a ratio of I-129/I typical of modern day surface seawater but is elevated in the concentration of I-129 (32 atoms/μl) because of bio accumulation of iodine in organic rich sediments and the subsequent release to the groundwater during methanogenesis. Production Wells #3 and 6 have I-129 levels consistent with I-129 from natural U fission. The three wells from the Vincentown (L,P and K at 80 feet)) all have similar concentrations and I-129/I ratios (Figure 1). In fact, Well K (the subject of possible "investigative concern") has lower I-129 and I-129/I than Well P , even though Well P has twenty times lower tritium (Figure 2) than K . The I-129/I ratio in K,L and P results from a mixture of Delaware River iodine (rich in I-129 but low in total iodine) and surface seawater that subsequently has concentrated on the organic matter in marshes adjacent to Salem. The iodine (and methane) dissolves in the groundwater during recharge, via the breakdown of organic rich sediments by methanogenesis. Waters from the 20 foot aquifer (O and N) have similar I-129/I

ratios but lower overall I-129 abundance because less methanogenesis and iodine release has occurred in these wells, close to Salem Unit #1.

1. INTRODUCTION

^{129}I ($T_{1/2}$ = 15.7 Ma; Emery et al., 1972) is produced naturally by the interaction of cosmic rays with xenon atoms in the atmosphere (Kohman and Edwards, 1966; Edwards and Rey, 1968), and by the spontaneous fission of ^{238}U in the subsurface (Purkayashtha and Martin, 1956). Since 1945, nuclear activities including power generation have produced orders of magnitude more ^{129}I than had previously existed at the surface of the earth. Activities such as weapons testing, fuel reprocessing, and accidents at nuclear power plants have released relatively large amounts of ^{129}I to the environment. This ^{129}I has dispersed globally and elevated the ratio of ^{129}I to stable iodine in the environment. Even with this increased background, localized releases of water containing elevated levels of ^{129}I (e.g. Spent Fuel Pool water or fuel reprocessing activity) can be observed over the background signal. Our goal is to exploit the high activity of ^{129}I in SFP water (10^{11} atoms/g) to investigate if SFP water has migrated away from Salem Unit #1 during the past 25 years of operation. Dissolved iodine moves at the rate of groundwater in the absence of organic-rich sediments. However, because of the biophilic character of iodine (Goldschmidt, 1954), ^{129}I from natural and anthropogenic sources may become sequestered in organic materials (such as marsh sediments). Groundwater that recharges through marshlands may acquire an anomalously high concentration of iodine, during the breakdown of the organic material (e.g. methanogenesis).

The amount of natural ^{129}I in the hydrosphere is estimated to be about 1×10^{27} atoms (~46 Ci) (Fabryka-Martin et al., 1985), most of it in the deep oceans. Pre-nuclear ^{129}I to stable iodine ($^{129}I/I$) ratios are on the order of 10^{-12} (Kohman and Edwards, 1966; Fabryka-Martin et al., 1985; Fehn et al., 1986; Kilius et al., 1992; Moran, 1994). World-wide nuclear weapons testing has added ~ 3×10^{26} atoms (12 Ci; Haury and Schikarski, 1977; Raisbeck et al., 1995), while the Chernobyl nuclear power plant accident released 2×10^{25} atoms (0.7 Ci; Schink et al., 1995). Although the total contribution from nuclear fuel reprocessing is not known, it is

estimated that the two large reprocessing facilities at Sellafield and La Hague themselves have contributed over 5 x 10^{27} atoms or 200 Ci of ^{129}I to the Atlantic Ocean (Zhou et al., 1993; Schink et al., 1995). Because anthropogenic ^{129}I is mainly confined to surface reservoirs (rivers, lakes oceanic mixed layer), $^{129}I/I$ ratios as high as 10^{-3} have been reported in some parts of the environment, especially around nuclear reprocessing facilities (Brauer, 1974). Because of the continued releases of ^{129}I from reprocessing, anthropogenic ^{129}I additions have swamped the natural budget, resulting in elevated $^{129}I/I$ ratios in surface waters worldwide. In the northeastern US, $^{129}I/I$ ratios are locally elevated because of the presence of a former nuclear fuel reprocessing facility (West Valley). Northern Hemisphere high latitude "bomb fallout" (10^{15} atoms/m^2), and several operating (and inactive) nuclear power plants , including the Three Mile Island reactor site in Pennsylvania do not appear to be major contributors to the ^{129}I inventory (Rao and Fehn, 1999). At West Valley, approximately 630 tons of commercial spent nuclear fuel were reprocessed during the operation of the facility during the 1970s. The gaseous nature of iodine releases during reprocessing results in the rapid dissemination of ^{129}I, probably as iodine and methyl iodide gases across large areas of the northeast US. Rapid cycling of ^{129}I between atmosphere, water, soil and vegetation results in elevated concentrations for this radioisotope in surface reservoirs for a long duration after a release event (early 1970s). If we assume that ^{129}I releases at the site were typical of reprocessing releases (9% of total ^{129}I production; UNSCEAR,1988), the West Valley facility released approximately 5 x 10^{25} atoms of ^{129}I during its years of operation. ^{129}I concentrations in water and soil samples around West Valley are elevated by more than 1000 and the effect diminishes with distance from the West Valley site. At West Valley, 85–90% of ^{129}I within each core was found to be bound up in the top 13–15 cm of soil, probably related to chemical and biological interactions with the organic-rich soil litter layer, and to high root density in the top few centimeters of surface soil. In contrast, the nuclear power plants in the region show only minor variation from typical ^{129}I concentrations across western New York and the northeastern US. At locations across North America, concentrations of ^{129}I are lower than those observed in western New York, but elevated above pre-nuclear concentrations by 500–10,000 times, even in such remote regions as the Canadian Arctic.

Previous Data and Justification

To investigate the potential sources of tritium contamination at Salem, we extend the use of radioactive tracers to include the long-lived radioactive isotope of iodine, ^{129}I (15.7 million year half life). The ^{129}I measurement by Accelerator Mass Spectrometry can detect ^{129}I at levels of 10^6 atoms and a $^{129}I/I$ ratio of 10^{-14}. Thus, this represents an extremely sensitive and long-lived tracer for radionuclide release. Iodine and tritium behave as "conservative" (non-reactive) tracers in groundwater in the absence of high concentrations of organic matter. A previous study at Ginna Nuclear Power Station has shown that different sources (secondary water, air-fall, spent fuel pool, natural groundwater) will have distinct concentrations of ^{129}I and distinct ratios of $^{129}I/^{3}H$. Steam from "secondary sources" has been shown to have extremely low ^{129}I concentrations (1000 atoms/g), presumably because of the procedures used to remove ions from solution to ensure the integrity of the steam generation process. Any leakage of secondary system water into the environment leaks mainly tritium (~10000 pCi/liter) and is not a major release mechanism for other radionuclides. The Turbine Drain samples from Ginna will serve as an analogue for the water that could leak during any steam (or secondary water) release (see Figure 2). Salem has slightly lower tritium concentrations in their "secondary water". At a nuclear power facility, only the Spent Fuel Pool contains significant levels of ^{129}I (10^{11} atoms/liter and $^{129}I/I$ ratios of 10^{-4}), above ambient levels in the NE region (10^8 atoms/liter and $^{129}I/I$ ratios of 10^{-7}) . There is a factor of 100000 difference between the ambient ^{129}I concentration in precipitation (10^6 atoms/liter) and Spent Fuel Pool water (10^{11} atoms/liter). A similar factor of about a million exists for tritium in precipitation (50pCi/liter) and spent fuel water (200 μCi/liter). From this simple comparison, one can estimate the maximum percentage of Spent Fuel Pool water that finds its way into any of the groundwater monitoring wells. Other sources of significant ^{129}I, may come from the combined effects of "wash down" from the containment building and seepage into the groundwater. This "wash down" has been observed at Ginna and must be evaluated as a potential source. The Ginna study demonstrated that the source of elevated tritium was related to the release of "secondary steam" from blowdown piping with no

contribution from the Spent Fuel Pool or Transfer Canal (both of which would have elevated ^{129}I).

A simple model based on the Ginna study would propose three potential "end-member" compositions for water at Salem : the Spent Fuel Pool water (high in tritium and high in ^{129}I), Turbine Drain (or secondary) Water (relatively high in tritium but very low in ^{129}I) and local precipitation (low in tritium and ^{129}I) . In this study, we have also observed an additional end-member that is low in tritium and high in ^{129}I that results from the concentration of ambient "post –nuclear" iodine in organic material and its release to groundwater during methanogenesis (i.e.bacterial breakdown of organic matter to methane). This last component will serve to increase the absolute concentration of ^{129}I observed in groundwater wells (up to 10^9 atoms/liter), absent any contribution from nuclear activities at Salem.

Salem Results

Groundwater Wells from Salem contain elevated levels of I-129 that are typical for waters in the northeastern US. There is no evidence of any addition of an I-129 rich component from the Spent fuel Pool. Three samples are "pre-nuclear" based on the low to "non-detect" levels of tritium (see Figure 1and 2). Well Q (at 80 feet) has a ratio of I-129/I typical of modern day surface seawater but is elevated in the concentration of I-129 (32 atoms/µl). Well Q recharges through organic-rich marsh sediments that initially sequesters iodine but then releases the iodine to the groundwater during methanogenesis (breakdown of organic matter by methane producing bacteria). Production Wells #3 and #6 also have levels of I-129 that are typical of ancient groundwater where spontaneous fission of uranium generates I-129. These waters are tritium-dead (as shown in Figure 2) and the I-129 results from natural nuclear reactions.

Figure 1 shows the Iodine-129 levels for five "nuclear-age" wells from both the 20 foot aquifer (O and N) and the 80 foot Vincentown (L,K,P). Shown for comparison are other local iodine reservoirs (e.g. Seawater and Susquehana river Water) and the mixing relation between the two. It is reasonable to assume that (in the absence of any nuclear activity) the local groundwater would lie on a mixing trajectory between the two. All of the five wells lie to the right of this mixing line in Figure 1 . There are no significant differences among the three wells

from the Vincentown (L,P and K). In fact, Well K (the subject of possible "investigative concern") has lower I-129 and I-129/I than Well P . Well P has twenty times lower tritium (Figure 2) than K (a tritium level that is completely consistent with precipitation 20 years ago). What is the reason for the elevated levels of I-129 seen in the wells around Salem? As stated above, it is known that organic material will concentrate iodine. During breakdown of this organic matter (methanogenesis), iodine will be released to the groundwater under reducing conditions. In fact, iodine concentrations in the Vincentown wells are higher than iodine in seawater. It is reasonable to assume that the ambient I-129/I ratio in the marsh (post 1960) is about 1E-9. This value would be consistent with a mix of seawater iodine and Delaware River iodine. The I-129/I ratio is preserved in the sediments as iodine is concentrated in organic matter. Methanogenesis releases the iodine that is bound up in organic matter to the groundwater (all of the Vincentown wells are methane-rich) and results in elevated levels of I-129 but with ratios that are completely consistent with "nuclear age" surface waters. In Figure 1, the line shows the trajectory for addition of SFP water. There is no evidence based on I-129 (or Tc-99) that Well K contains any activity from an SFP leakage. However, because of the elevated natural levels of I-129 in Vincentown groundwater, the difference in I-129 between Well K and the SFP is only a factor of 100, where they differ by 100,000 in tritium. Thus, one cannot completely exclude the presence of an SFP component (<10 ppm) in Well K, although addition of about 1% "secondary water" makes better hydrologic sense.

Waters from the 20 foot aquifer (O and N) have similar I-129/I ratios but lower overall I-129 abundance because less methanogenesis and iodine release has occurred in these wells, close to Salem Unit #1. There is a slight indication from Figure 2 that a minor amount of SFP water is present at Well N, but the results are far from conclusive.

ANALYTICAL PROCEDURES for IODINE

Water samples were prepared for ^{129}I /I ratio measurement by an adaptation of the method described in Fehn et al., 1992. Approximately 100 mL of water was used as starting material for sample preparation except for the two samples with the highest expected ratios where 1 mL and

0.1 mL were used. Since samples were expected to have high ^{129}I /I ratios and low iodine concentrations, carrier iodine with low ^{129}I content was added to each sample prior to extraction. Addition of carrier serves the dual purpose of increasing sample bulk to facilitate measurement, as well as preventing cross-contamination in the source from "hot" samples, i.e., samples high in ^{129}I, during Accelerator Mass Spectrometry (AMS) measurements. To achieve isotopic equilibrium between the sample and carrier KI which is added, samples and carrier were converted to IO_4^-. Iodine in the samples was then extracted into CCl_4, and back-extracted into the aqueous phase, followed by precipitation as AgI powder, following standard procedures. The silver iodide was pressed into stainless steel sample holders and loaded on a sample wheel for AMS measurement.

^{129}I -to-stable iodine ratios (^{129}I /I) were determined by AMS at the PRIME lab facility at Purdue University. AMS uses a tandem accelerator in conjunction with an ion source, several magnets and suitable detectors to sensitively measure atoms of choice with detection limits of one atom in 10^{15} stable atoms, with associated removal of interfering atoms (see Elmore et al. (1984a and 1984b), Kubik et al. (1987) for a detailed description of AMS techniques). ***(This facility is the only one currently in operation in the U.S that can perform the analysis at the required levels of precision).*** The ^{129}I /I ratios were normalized to a known standard during AMS measurement. AMS has a theoretical detection limit of $^{129}I/I$ ratio = 1×10^{-15} although practical detection limits are about 50×10^{-15}, due to the lack of natural materials with lower ^{129}I /I ratios. Chemical blanks and carrier iodine had ^{129}I /I ratios of 80 x 10-15 during that AMS run. I- content in the carrier solution was measured by ion chromatography with errors of +/- 5%.

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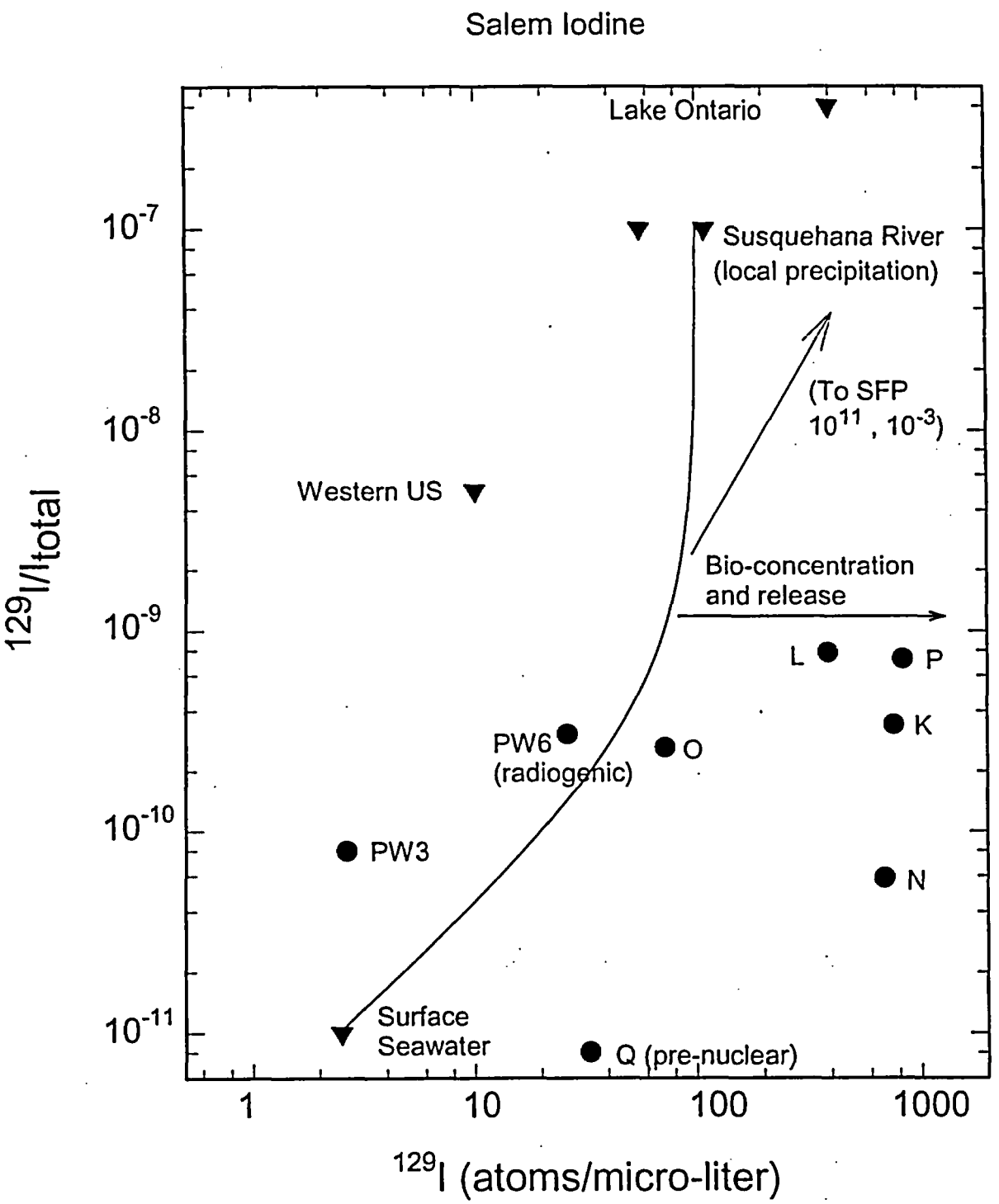
Salem Iodine
Lake Ontario
Susquehana River
(local precipitation)
(To SFP
10^{11} , 10^{-3})
Western US
Bio-concentration
and release
L
P
K
O
PW6
(radiogenic)
PW3
N
Surface
Seawater
Q (pre-nuclear)
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-11}
1
10
100
1000
$^{129}I/I_{total}$
^{129}I (atoms/micro-liter)

Figure 1

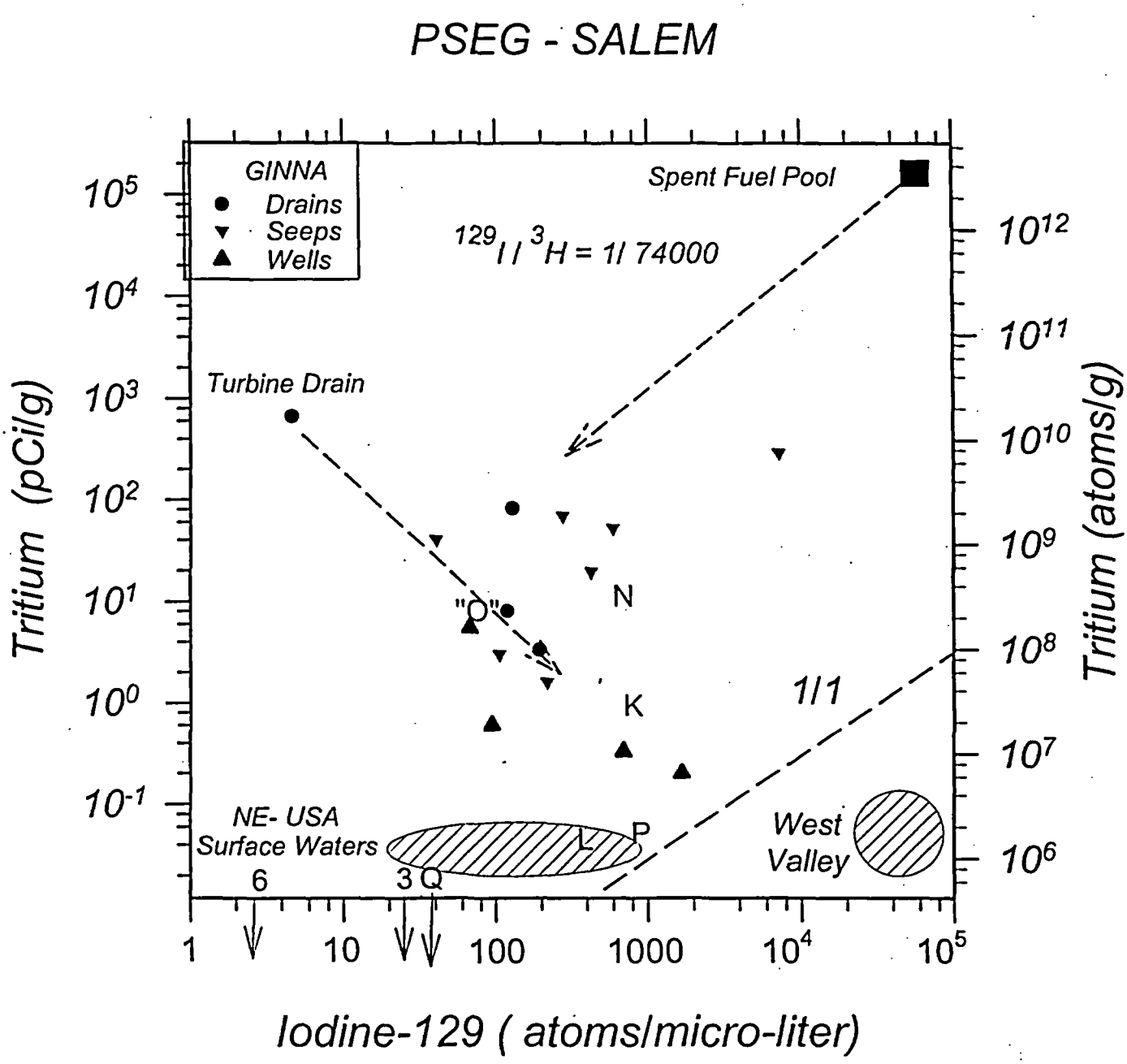
PSEG - SALEM
GINNA
Drains
Seeps
Wells
Spent Fuel Pool
$^{129}I / ^{3}H = 1/ 74000$
Turbine Drain
"Q"
N
K
1/1
NE- USA
Surface Waters
6
3
Q
L
P
West
Valley
10^5
10^4
10^3
10^2
10^1
10^0
10^{-1}
Tritium (pCi/g)
10^{12}
10^{11}
10^{10}
10^9
10^8
10^7
10^6
Tritium (atoms/g)
1
10
100
1000
10^4
10^5
Iodine-129 (atoms/micro-liter)

Figure 2

Sample	$^{129}I/I$	I	^{129}I	$^{129}I/I$	error	Tritium
	$x10^{-15}$	ppb	atoms/µL	$x10^{-15}$	$x10^{-15}$	pCi/liter
Q80-030425	2380	863	32.9	8040	550	1.6
O20-030424	1150	58	72.1	262100	34600	6000
PSEG-Well N	9470	2479	688.0	58550	2350	12500
PSEG-PW6	1900	18	26.1	306300	44300	<0.5
K80-030424	50300	470	761.2	341650	20600	955
L80-030424	19900	105	387.9	779400	31400	45
P80-030424	55400	243	835.4	725300	35600	58
PSEG-PW3	358	7	2.64	79700	29100	<0.5

Appendix B

Groundwater Modeling Results

Development of a Groundwater Flow and Solute Transport Model

Salem Generating Station

PREPARED FOR

PSEG, Inc.

ARCADIS

Figures

Tables

Executive Summary

PSEG retained ARCADIS G&M, Inc. (ARCADIS) to conduct groundwater flow and transport modeling at the Salem Generating Station near Salem, New Jersey (the Site), as part of an investigation focusing on tritium in site groundwater. The primary objective of this modeling study is to better understand the current nature, extent, and fate of tritium in groundwater, and to support the overall assessment of remediation alternatives to control potential migration of tritium to surface waters. Modeling results provide information that will be used to quantify environmental conditions (i.e., analysis of potential surface water impacts from groundwater seepage) and evaluate potential remedial actions.

The development, construction, and calibration of groundwater flow and solute transport models are detailed in this modeling report. Existing hydrogeologic Site data were used, along with additional regional information found in the literature, to develop, construct, and calibrate the flow and transport models. Flow and transport simulations were performed to evaluate the future migration of tritium in groundwater beneath the Site. The modeling study focused on groundwater movement in the sands above the Kirkwood formation (shallow groundwater) to determine if tritium is currently discharging, or has the potential to discharge, to the Delaware River.

MODFLOW, a publicly-available simulation program developed by the U.S. Geological Survey (USGS) (McDonald and Harbaugh, 1988), was selected for the groundwater flow. MODFLOW is thoroughly documented, widely used by consultants, government agencies and researchers, and is consistently accepted in regulatory and litigation proceedings. In constructing the flow model for the site, representative values for model parameters were selected based on site-specific data. These values were adjusted as the groundwater flow model was calibrated using water-level elevations measured in monitoring wells distributed throughout the Site. These calibration targets were measured in March 2004 and comprise a total of 22 monitoring wells, each of which is screened across multiple model layers. Therefore, the 22 monitoring wells represent 65 water level targets or objectives to which the groundwater model was calibrated. A sensitivity analysis was performed to examine the effects of uncertainties in each of the model calibration parameters.

After flow calibration, solute transport modeling was used to evaluate the movement of tritium through the groundwater system to evaluate if tritium will discharge to the Delaware River.

The MT3DMS computer code developed by the U.S. Environmental Protection Agency (Zheng and Wang, 1998) was selected for solute transport modeling. MT3DMS, which uses the MODFLOW groundwater flow and velocity terms in transport calculations, is also a publicly available computer program that features extensive documentation and verification. MT3DMS also uses the same finite-difference grid structure and boundary conditions as the groundwater flow model, minimizing the effort necessary to construct a solute transport model.

Three solute transport scenarios were performed to evaluate the movement of tritium at the Site. All transport simulations were initialized using the most recent observed tritium concentration data. Each transport scenario was simulated for a 10 year period (2004 to 2014) and is summarized as follows:

1. **Scenario 1: Existing Conditions** – no active remediation was performed and the plume was assessed to determine, if and at what levels tritium could discharge at the site boundary

2. **Scenario 2: Pilot Study Wells Pumping** – long term groundwater pumping using only the 4 wells selected for the pilot study to assess groundwater pump and treatment.

3. **Scenario 3: Full Scale Remediation** – long term groundwater pumping using a total of 9 wells.

The results from scenario one show that if no action is taken, the majority of the tritium plume will eventually discharge to the Delaware River, predicating the need for active remediation. Scenario 2 shows that the 4 pilot study wells can control the movement of tritium; however, as the pilot test is not designed or intended to be a full scale remedial system, it does not efficiently recover tritiated groundwater. After 10 years, the pilot study wells have extracted 7.22 curies of tritium, representing approximately 73 % of the current plume (conservatively assumed to be 9.84 curies), and only 7.8 % of the 2004 tritium plume is still in the ground (the remaining balance is a function of natural decay). Scenario 3 shows that full scale remediation utilizing 9 recovery wells will be more efficient in the short term and better ensure on-site capture of groundwater as they extract more water; however, full scale remediation in the long term will only be marginally more effective at removing tritiated groundwater. After 10 years, the nine recovery wells have extracted 7.83 curies of tritium, representing approximately 80 % of the current plume of 9.84 curies, and only 4.3 % of the 2004 tritium plume is still in the ground (similarly, the remaining balance is a function of natural decay).

1. Introduction

ARCADIS, Inc. ("ARCADIS"), on behalf of PSEG Services Corporation ("PSEG SC"), has developed a three-dimensional numerical groundwater flow and solute transport model 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 project activities associated with modeling groundwater conditions at the site are summarized in this report.

1.1 Objectives And Scope

The detailed project background is found in the Remedial Investigation Report (RIR) submitted in March 2004. The remedial investigation identified an area of tritiated groundwater adjacent and south of the Shield Building and the Fuel Handling Building associated with Unit 1 (Figure 3). Groundwater conditions in this area are the focus of the current study. The objective of this modeling study is to develop a groundwater flow and solute transport model to evaluate various remedial measures to control the future migration of tritium to surface waters. The selected remedial measures are based upon an assessment of current groundwater conditions including: groundwater-surface interactions; subsurface infrastructures, facility operations; and current tritium concentrations. The existing hydrogeologic data collected at the Site and additional regional information were used in the development of the model.

This modeling report describes all aspects of the modeling performed for the study. The phases of work were completed in a systematic fashion as follows:

- Data review and development of the conceptual model of groundwater flow conditions;
- Construction of a three-dimensional numerical groundwater flow model;
- Calibration of the groundwater flow model to observed water levels at the Site;
- Model sensitivity and flow system analyses;
- Construction of a three-dimensional numerical solute transport model; and

- Simulation of the fate and transport of tritium with and without operation of a groundwater extraction system to evaluate future subsurface conditions, potential surface water impacts, and the effectiveness of remedial alternatives.

2. Conceptual Model

A conceptual flow model is a narrative description of the principle components of a groundwater flow system. The primary components of a groundwater flow system typically include: (1) areal extent, configuration, and type of aquifers and aquitards; (2) hydraulic properties of aquifers and aquitards; (3) natural groundwater recharge and discharge zones; (4) anthropogenic groundwater sources and sinks; and, (5) areal and vertical distribution of groundwater hydraulic head potential. These aquifer system components serve as the framework for the construction of a numerical groundwater flow model. The conceptual model strives to achieve a balance between the complexity of the actual field data and the inherent simplifications necessary for quantitative interpretation and mathematical modeling.

A conceptual model for the Site has been developed from regional, local, and site-specific hydrogeologic data collected by ARCADIS and other consultants, including: (1) well logs and geologic information; (2) water level data; (3) aquifer hydraulic properties; (4) precipitation data; (5) review of available hydrologic studies for the site and vicinity; and (6) collection and interpretation of pumping test data. The existing site data are sufficient to develop a detailed and accurate conceptual model that will allow for efficient translation of the physical conditions at the site to the numerical computer model. The following sections describe the hydrogeology within the vicinity of the Site.

2.1 Site Geology

The Salem Generating Station is located on the eastern shore 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 2.3.

The geologic formations beneath the shallow, water-bearing unit, in order of increasing depth, are as follows: the Kirkwood Formation/unnamed clay confining unit; 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 4 (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.

2.1.1 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 high in TDS and is not considered a source of drinking water.

2.1.2 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).

2.1.3 Kirkwood Formation

The Kirkwood Formation (or unnamed clay confining unit), 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. The Kirkwood formation represents the bottom of the shallow groundwater flow system and the bottom of the groundwater model. The elevation of the top of the Kirkwood Formation is shown on Figure 5.

2.1.4 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 (unnamed clay confining unit), 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, a regionally extensive formation.

2.2 Site Hydrogeology

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. 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.

2.3 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.

2.4 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. Figure 6 is a representative cross-section showing the hydrogeologic details in the area of interest.

2.4.1 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 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).

2.4.2 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.

2.4.2.1 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.

2.4.2.2 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.

2.4.2.3 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.

2.4.3 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.

2.4.4 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.

2.4.5 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.

2.4.6 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, 11.5-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 approximately 4 feet thick, 6 feet wide and 75 feet long (dimensions estimated from historical photographs) 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 groundwater flow barrier, vertically extending 16 to 20 feet through the shallow aquifer at the site. Construction of the return circulating water pipes was completed by placement and compaction of structural fill from near the top of the pipes to the present land surface.

2.4.7 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.

2.5 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 is laterally extensive across Artificial Island and vertically extends from the top of the Kirkwood basal sand to approximately 60 feet PD (-30.53 feet amsl). The Kirkwood Aquitard is ten to twenty feet in thickness and is composed of hard tan to gray clay with some sand and silt. A recent pollen analyses of this clay indicates that it may be of much younger age (Pleistocene rather than Miocene) and therefore not the Kirkwood Formation but rather an unnamed clay unit. 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).

2.6 Groundwater Elevations

Groundwater levels collected from Site monitoring wells in March 2004 were used to prepare a water level contour map of the shallow aquifer (Figure 7). The water level elevations are summarized in Table 2. Figure 7 shows groundwater flow is generally from the center of the Island (northeast of the power block) toward the Delaware River; however, Due to permeability differences between the structural fill around the power block and the hydraulic fill, as well as building foundations and subsurface infrastructure, groundwater is mounded within the cofferdam. Groundwater flows radially outward from the coffer dam and the observed mounding effect dissipates quickly.

3. Groundwater Flow Model Construction

This section describes the construction and calibration of the groundwater flow model for the Site. The primary phases in the development of a numerical groundwater flow model include the construction of a finite-difference grid, specification of model layer top and bottom elevations, assignment of boundary conditions, selection of appropriate water-level measurements for calibration of the model, and finally specification of hydraulic parameter values and zones. This information forms the basis for subsequent calibration of the numerical model to observed groundwater flow conditions at the Site.

The following sections describe the code selection, discretization, boundary conditions, and calibration procedure employed.

3.1 Code Selection and Description

The code MODFLOW, a publicly-available groundwater flow simulation program developed by the U.S. Geological Survey (USGS) (McDonald and Harbaugh, 1988), was selected for the construction and calibration of the three-dimensional groundwater flow model at Site. MODFLOW is thoroughly documented, widely used by consultants, government agencies and researchers, and is consistently accepted in regulatory and litigation proceedings. In addition, ARCADIS has developed utilities for use with MODFLOW to ease in the construction and calibration of groundwater models.

MODFLOW can simulate transient or steady-state saturated groundwater flow in one, two, or three dimensions and offers a variety of boundary conditions including specified head, areal recharge, injection or extraction wells, evapotranspiration, drains, and rivers or streams. Aquifers simulated by MODFLOW can be confined or unconfined, or convertible between confined and unconfined conditions. For the Site, which consists of a heterogeneous geologic system with variable unit thickness and boundary conditions, MODFLOW's three-dimensional capability and boundary condition versatility are essential for the proper simulation of groundwater flow conditions.

MODFLOW simulates transient, three-dimensional groundwater flow through porous media described by the following partial differential equation for a constant density fluid:

$$\frac{\partial}{\partial x}\left(K_{xx}\frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial y}\left(K_{yy}\frac{\partial h}{\partial y}\right)+\frac{\partial}{\partial z}\left(K_{zz}\frac{\partial h}{\partial z}\right)-W=S_s\frac{\partial h}{\partial t} \qquad (3\text{-}1)$$

where

K_{xx}, K_{yy} and K_{zz} are values of hydraulic conductivity along the x, y, and z coordinate axes, which are assumed to be parallel to the major axes of hydraulic conductivity [L/T];

h is the potentiometric head [L];

W is a volumetric flux per unit volume and represents sources and/or sinks of water [1/T];

S_s is the specific storage of the porous material [1/L]; and

t is time [T];

In Equation 3-1, the hydraulic parameters (i.e., K_{xx}, K_{yy}, K_{zz} and S_s) may vary in space but not in time; the source/sink (W) terms may vary in both space and time.

MODFLOW uses a numerical approximation technique known as the method of finite differences to solve Equation 3-1 on a computer. Using a block-centered finite-difference approach, MODFLOW replaces the continuous system represented in Equation 3-1 by a set of discrete points in space and time. This process of discretization ultimately leads to a system of simultaneous linear algebraic equations. MODFLOW solves these finite-difference equations with one of the following three iterative solution techniques: strongly implicit procedure (SIP), slice-successive over-relaxation (SSOR), or preconditioned conjugate gradients (PCG). The solution of the finite-difference equations produces time-varying values of head at each of the discrete points representing the real aquifer system. Given a sufficient number of discrete points, the simulated values of head yield close approximations of the head distributions given by exact analytical solutions to Equation 3-1.

3.2 Model Discretization

The finite-difference technique employed in MODFLOW to simulate hydraulic head distributions in multi-aquifer systems requires areal and vertical discretization or subdivision of the continuous aquifer system into a set of discrete blocks that form a three-dimensional model grid. In the block-centered finite-difference formulation used in MODFLOW, the center of each grid block corresponds to a computational point or node. When MODFLOW solves the set of linear algebraic finite-difference equations

for the complete set of blocks, the solution yields values of hydraulic head at each node in the three-dimensional grid.

Water levels computed for each block represent an average water level over the volume of the block. Thus, adequate discretization (i.e., a sufficiently fine grid) is required to resolve features of interest, and yet not be computationally burdensome. MODFLOW allows the use of variable grid spacing such that a model may have a finer grid in areas of interest where greater accuracy is required and a coarser grid in areas requiring less detail.

The three-dimensional model grid developed for the Site covers approximately 28 acres (i.e., active model region). The model grid was oriented approximately northwest-southeast. The boundaries of the model grid are specified to coincide with natural hydrogeologic boundaries, where possible. The boundaries were defined at a significant distance from the site to minimize the influence of model boundaries on simulation results at the site. The active model domain is approximately 1,085 feet along the northeast-southeast boundary at the widest point and 1,115 feet along the northwest-southwest boundary. The finite-difference grid is composed of 223 columns, 217 rows, and 10 layers for a total of 483,910 nodes. The model grid uses a uniform 5-foot areal grid spacing throughout the entire model domain. The extent of the finite-difference grid encompasses the entire local groundwater flow system impacted with tritiated groundwater and the 5-foot areal grid spacing used is sufficiently fine for the purpose of accurately simulating groundwater flow conditions. The extent chosen for the grid ensured adequate incorporation of groundwater flow features that affect conditions at the site. Fine discretization at the Site also allowed for sufficient detail to match site measurements. Meeting both of these objectives is essential for the calibration of the groundwater flow model.

Similarly, the vertical discretization was developed to represent key structural elements of the facility infrastructure, the three-dimensional extent of the plume, as well as to be approximately the same as the horizontal grid spacing. Layer 1 has a variable thickness extending from the water table to an elevation of 88 ft PD. Near the Delaware River this layer is approximately 2 feet thick, while inside the cofferdam it is approximately 6 feet thick. The tops and bottoms of Layers 2, 3, and 4 are 88 ft PD and 85 ft PD, 85 ft PD and 82 ft PD, and 82 ft PD and 78 ft PD, respectively. The bottom of layer 4 is the top of the cofferdam along the western and southern portion of the power block. The tops and bottoms of layers 5, 6, and 7 are 78 ft PD and 74 ft PD, 74 ft PD and 70 ft PD, and 70 ft PD and 66 ft PD, respectively. The tops and bottoms of layer 8, 9, and 10 are 66 ft PD and either the Kirkwood formation or 62 ft PD, 62 ft

PD and either the Kirkwood formation or 58 ft PD, and 58 ft PD and the top of the Kirkwood formation, respectively.

3.3 Boundary Conditions

Boundary conditions must be imposed to define the spatial boundaries of the model on the top, bottom, and all sides of the model grid. In addition to these boundary conditions, sources and sinks of groundwater such as wells and rivers can be included within the model boundaries. A boundary condition can represent different types of physical boundaries, depending on the rules that govern groundwater flow across the boundary. The external model boundaries were chosen to coincide with natural surface-water discharge points in the area where possible. The Site flow model includes four types of boundary conditions: no-flow, recharge (constant flux), constant head (head dependent flow), and wells (constant flux). The location and types of boundary conditions in each layer of the model are shown in Figure 8 through Figure 17.

The Delaware River is located within the model domain are represented in the MODFLOW model using constant heads. Constant heads allow for the specification of a known water elevation. These conditions are typically associated with large surface water bodies which act as the principle source or discharge point of the groundwater flow system (McDonald and Harbaugh, 1988). The mean water level of the Delaware River is 90.09 PD based upon the site staff gage and the USGS data from Alloways Creek.

Prior to the installation of the groundwater extraction wells for the pilot test, there was no groundwater pumping within the model domain. No-flow boundaries were used in the model to define the limits of the water bearing units each for the 10 layers and where buildings and subsurface infrastructure are present. The no-flow boundaries were also chosen to coincide with inferred flow lines west and east of the power block.

3.4 Calibration Targets

Calibration targets are a set of field measurements, typically groundwater elevations, used to test the ability of a model to reproduce observed conditions within a groundwater flow system. For the calibration of a steady-state (time-invariant) model, the goal in selecting calibration targets is to define a set of water-level measurements that represent the average elevation of the water table or potentiometric surface at locations throughout the model domain.

The March 2004 water levels (Figure 7) collected from the 22 monitoring wells within the model domain were used to calibrate the model. Each of these monitoring wells intercepts multiple layers in the groundwater model. Therefore, from a modeling perspective, each well represents multiple water level observations and the 22 monitoring wells represent 65 calibration targets. Table 1 summarizes each model layer intercepted by each monitoring well.

3.5 Hydraulic Parameters

In constructing the model for the Site, representative values for model parameters were selected based on site-specific data. These model parameters included aquifer recharge and horizontal hydraulic conductivity of the aquifer. Initially, a single zone of recharge was added to the model to represent the fraction of total precipitation reaching the water table (i.e., precipitation recharge). The model also included separate values or zones of hydraulic conductivity for each aquifer material encountered at the Site, and was initially constructed with a uniform hydraulic conductivity for each layer that reflected conductivity values based on aquifer tests. During the calibration of the model, parameter values and the extents of zones of similar hydrogeologic properties were adjusted to minimize the difference between observed and simulated groundwater elevations.

Two parameters, recharge and the hydraulic conductivity of the aquifers, were varied during the calibration of the model from their initial values to match measured and simulated water-level elevations at the calibration targets. Though initially constructed with a uniform hydraulic conductivity for each layer, hydraulic conductivity zones were added and parameter values were adjusted as necessary during calibration to minimize the difference between observed and simulated groundwater elevations. In order to match the hydraulic gradients, four different hydraulic conductivity zones were identified in the model. Zone 1 (K_1=6.5 ft/day) represents the majority of the sediments beneath the site. Zone 3 (K_3=0.4 ft/day) corresponds to the material compacted around the foundations of the power block and around the recirculation water pipes. Zone 2 (K_2=2.5 ft/day) corresponds to the soils beneath the foundations of the turbine building, and Zone 4 (K_4=0.125 ft/day) corresponds to the soils beneath the foundation for crane associated with the equipment hatch for the Unit 1. The extent of each zone in each layer is presented on Figures 8 through 17.

Areal recharge reaching the water table was characterized using 5 different values. Zone 1 (R_1=8.5 in/yr) represents most of the model domain characterizing average conditions at the Site. Zone 2 (R_2=0.0 in/yr) corresponds to buildings which prevent local recharge. Zone 3 (R_3=0.33 in/yr) represents the area between the turbine building

and the power block. Zone 4 (R_4=0.0.82 in/yr) corresponds to the area between the Fuel Handling Building and the Auxiliary Building. Zone 5 (R_5=20 in/yr) is a limited area near well soils beneath the foundation for crane associated with the equipment hatch for the Unit 1. The extent of each zone in each layer is presented on Figures 18.

4 Groundwater Flow Model Calibration

Calibration of a groundwater flow model refers to the process of adjusting model parameters to obtain a reasonable match between observed and simulated water levels. In general, model calibration is an iterative procedure that involves variation of hydraulic properties or boundary conditions to achieve the best match between observed and simulated water levels. During model calibration, site-specific data and interpretations from previous investigations are used as a guide to constrain estimates of hydraulic conductivity.

4.1 Calibration Procedure

For best results, the calibration of a model should rely on discrete measurements to produce answers free of contouring interpretations. During the calibration of a groundwater flow model, the use of point data eliminates the potential for interpretive bias that may result from attempting to match a contoured potentiometric surface (Konikow 1978; Anderson and Woessner 1992). The groundwater flow model for the Site is calibrated using 65 water-level calibration targets measured in 22 site monitoring wells.

As a further goal for the calibration of a model, the principle of parameter parsimony is applied to achieve an adequate calibration of the model through the use of the fewest number of model parameters. It should be noted that the use of greater numbers of model parameters during model calibration creates a situation in which different combinations of model parameter values produce similar calibration results. In this case, the model calibration parameters are called non-unique. Following the principal of parameter parsimony reduces the degree of non-uniqueness and results in more reliable calibrated parameter values. The information gathered for the conceptual model guides any decision to add model parameters (e.g., zones of hydraulic conductivity) to the model during the calibration process. Therefore, in the absence of hydrogeologic evidence, the simpler model is preferred.

ARCADIS routinely uses an automatic parameter estimation procedure to calibrate groundwater flow models. Starting with a set of initial estimates for the model parameters, the procedure systematically updates the parameter estimates to minimize the difference between simulated and observed water levels at a set of calibration targets. Compared to trial-and-error procedures for model calibration, automatic parameter estimation can greatly reduce the time required for model calibration and generally provide a better overall calibration. The general algorithm applied in

conjunction with the MODFLOW code is known as the Gauss-Newton method and is described in greater detail by Duffield et al. (1987) and Hill (1992).

The primary criterion for evaluating the calibration of a groundwater flow model is the difference between simulated and observed water levels at a set of calibration targets. A residual or model error, e_i, is defined as the difference between the observed and simulated hydraulic head measured a target location:

$$e_i = \hat{h}_i - h_i \qquad (4\text{-}1)$$

where h_i is the measured value of hydraulic head and $\hat{h}_i$ is the simulated value at a specific target location. A residual with a negative sign indicates underprediction by the model (i.e., the simulated head is lower than the measured value). Conversely, a positive residual indicates overprediction.

The automatic parameter estimation procedure seeks to minimize an objective function defined by the residual sum of squares (*RSS*):

$$RSS = \sum_{i=1}^{n} (\hat{h}_i - h_i)^2 \qquad (4\text{-}2)$$

where n is the total number of calibration targets. The *RSS* is the primary measure of model fit. The residual standard deviation (*RSTD*), which normalizes the RSS by the number of calibration targets and number of estimated parameters (p), is defined as follows:

$$RSTD = \sqrt{\frac{RSS}{n - p}} \qquad (4\text{-}3)$$

The *RSTD* is useful for comparing model calibrations with different numbers of calibration targets and estimated parameters. Another calibration measure is the mean of all residuals ($\bar{e}$):

$$\bar{e} = \frac{1}{n} \sum_{i=1}^{n} e_i \qquad (4\text{-}4)$$

A mean residual significantly different from zero indicates model bias. The Gauss-Newton parameter estimation procedure produces a near zero mean residual at the minimum *RSS*.

4.2 Calibration Results

The groundwater flow model calibration required numerous individual computer simulations. The values and shapes of the various parameter zones in the model were gradually varied until a reasonable solution was achieved in agreement with the conceptual model. The 65 water-level targets selected for the calibration of the groundwater flow model were used to evaluate the calibration of the model through the analysis of (1) simulated hydraulic head distributions in the model layers, (2) residual statistics and (3) estimated hydraulic parameters.

4.2.1 Simulated Hydraulic Head Distributions

As a part of evaluating the calibration of the numerical model, simulated potentiometric surface maps are prepared for each of the model layers to depict groundwater flow conditions in the vicinity of the Site (Figures 19 through 28). From the simulated groundwater contours in each model layer, it is apparent that groundwater generally flows from the power block toward the Delaware River, which is consistent with the observed water levels at the Site. Near the river, contours reflect the influences of the sheet piling and seismic structures which deflect and limit flow towards the river.

4.2.2 Analysis of Residuals

The calibration of the groundwater flow model for the Site sought to minimize the residual sum of squares (Equation 4-2) computed for the 65 water-level calibration targets. Table 2 lists the simulated water elevations and model residuals for each of the calibration targets. The maps of simulated hydraulic heads (Figures 19 through 28) show the spatial distribution of these residuals in each model layer. The largest computed residual for the entire set of targets is -1.62 ft in well AL. Eighty-eight percent of the targets have residuals less than 6 inches or less than 10 percent of the range in water levels across the site. Overall, the model shows a very good match to the measured water levels at the Site. Figure 29 shows the agreement between observed and simulated water levels graphically with 10 percent error bars about the mean.

Residual statistics for the calibrated groundwater flow model indicate good agreement between simulated and measured groundwater elevations. The residual mean and residual sum of squares for the calibrated model are also shown in Figure 29. The residual standard deviation was calculated to be 0.42 ft. The mean is close to zero (0.07 ft) and residual sum of squares is 11.21 ft^2. These statistics show that a high level of calibration standard has been achieved in this modeling effort and, overall, the model shows a very good match to the measured water levels at the site.

4.3 Sensitivity Analysis

A sensitivity analysis was performed to examine the effects of uncertainties in each of the model calibration parameters. The response of the calibrated model (as indicated by the changes to the *RSS*) to changes in the horizontal hydraulic conductivity and recharge for each parameter zone was evaluated through a discrete sensitivity analysis. In this analysis, one parameter at a time was varied while all other parameters were held constant. Each calibrated parameter value was, in turn, multiplied by factors between 0.5 and 3.0 (i.e., a multiplier of 1.0 corresponds to the calibrated value of the parameter). No significant improvement was achieved in the model calibration by these parameter changes. The results of the sensitivity analysis for horizontal hydraulic conductivities, recharge, and leakance are shown graphically in Figures 30 through 33, respectively.

4.4 Pathline Analysis

Particle tracking analyses were performed to determine hydraulic pathways for contaminant migration. The particle tracking scenarios were evaluated using the U.S. Geological Survey particle tracking code MODPATH (Pollack 1989). Particle tracking techniques are useful tools for evaluating groundwater flow rates and directions. Particle tracking is a simple form of solute transport analysis which qualitatively evaluates non-aqueous or dissolved phase constituent migration pathways. The directions of movement of constituents are evaluated based on the simulated water levels which provide a quantitative estimate of the flow rate and direction of constituent movement. Particle tracking simulates the migration pathway of dissolved constituents as purely an advective process and ignores the processes of dispersion, adsorption, and decay. From an initial starting point, particle tracking simulates the movement of a particle of water through a groundwater flow field over time. Reverse particle tracking traces the previous positions of the particle backward in time from a specified end point. Reverse particle tracking is very useful for showing the zone of capture for recovery wells, groundwater collection trenches, and horizontal recovery wells. The results of the particle tracking analysis are shown in Figure 34. Particles

were started placed along the shore of the Delaware River and reverse particle tracking was used to identify groundwater flow pathways.

5 Groundwater Solute Transport Modeling

Activities at the Site have resulted in elevated concentrations of tritiated groundwater. The objective of the transport simulations is to predict the migration and future distribution of this constituent as well as provide guidance in screening remedial alternatives for the Site. Simulations are performed that account for degradation, dispersion, and effective retardation of the tritium. The solute transport model uses the velocity field output from the calibrated flow model to predict the movement of the dissolved constituents by simulating the physical processes of advection, dispersion, and radioactive decay.

Three solute transport scenarios were evaluated the movement of tritium at the Site considering pure advectimovement and each are described below. All transport simulations were initialized using the March 2004 observed tritium concentrations data. Each transport scenario was simulated over a 10 year period and is described as follows:

1. **Existing Conditions** – no active remediation was performed and the plume was assessed to determine, if and at what levels tritium would discharge at the site boundary

2. **Pilot Study Wells Pumping** – long term groundwater pumping using only the 4 wells selected for the groundwater pump and treatment pilot study.

3. **Full Scale Remediation** – long term groundwater pumping using a total of 9 wells.

5.1 Code Selection

The MT3DMS computer code developed by the U.S. Environmental Protection Agency (Zheng and Wang, 1998) was selected for solute transport modeling. MT3DMS is a publicly-available computer program that features extensive documentation and verification. The code is fully three-dimensional, simulates transport in confined and unconfined flow systems, and can account for hydrodynamic dispersion, adsorption (retardation), and decay in solute transport calculations. MT3DMS was chosen for this modeling application because it was designed to be used in conjunction with MODFLOW (McDonald and Harbaugh, 1988), which was used in the groundwater flow-modeling task of this investigation. MT3DMS uses the groundwater flow and velocity terms from MODFLOW in the transport calculations. MT3DMS also uses the same finite-difference grid structure and boundary conditions as the groundwater flow model, minimizing the effort necessary to construct a solute transport model.

MT3DMS has five methods for solving the advective-dispersion equation, including the Method of Characteristics (MOC), the Modified Method of Characteristics (MMOC), the Hybrid Method of Characteristics (HMOC), the third-order total-variation-diminishing (TVD) method, and a conventional explicit finite-difference technique. An advantage of the MOC technique is that numerical dispersion is very low. However, this method is computationally intensive. The MMOC method involves fewer computations, but induces more numerical dispersion where steep concentration gradients are present. The HMOC technique is a mixture of MOC and MMOC, and attempts to combine the strengths of both through an automatic adaptive procedure. The TVD method is essentially a higher-order finite-difference method that has been recently added to the code. The TVD method may have limited numerical dispersion, but the computational burden is much greater than the standard finite-difference method. The finite-difference technique uses a Taylor-series to approximate the derivatives, and is susceptible to numerical dispersion. Based upon the moderately steep concentration gradients that have been observed in the field the explicit finite-difference procedure was used. The time step size is based upon the selected model parameters, the size of the finite-difference grid, and the maximum pore water velocities in the groundwater model.

5.2 Transport Parameters

The simulation of solute migration requires specification of various transport parameters that control the rate, movement, mixing, adsorption, 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 mixing of the contaminant in the groundwater due to non-ideal flow paths in the aquifer medium. Adsorption 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.

The simulation of advective transport requires a definition of effective porosity to compute interstitial groundwater velocities. The total porosity of the sands was estimated to be 35%. The bulk density was computed from the total porosity to be 1.72 grams per cubic centimeter. The effective porosity was assumed to be 20%, the recommended value for sands and gravels (USEPA, 1989).

The retardation factor (R_f) is used by the solute transport model to represent the amount of adsorption of a constituent between the dissolved or solute phase and adsorbed to the aquifer. Tritium is a refractory or non-retarded constituent as it is simply a form of water. However, while tritium moves through the active pores (effective porosity) a

portion diffuses into dead end pore spaces (the difference between total porosity, 35%, and effective porosity (20%). This process of diffusion slows the forward movement of the constituent, resulting in an effective retardation. Mathematically, the effective retardation can be expressed one plus the ratio of immobile to mobile pores (Leismann et al., 1988) according to the following equation:

$$R_f = 1 + \frac{\theta_i}{\theta_m} \qquad (5\text{-}1)$$

The change in mass of a constituent due to first-order degradation processes can be represented mathematically as:

$$M = M_0 e^{-\lambda t} \qquad (5\text{-}2)$$

where M is the non-degraded mass at some time t, M_0 is the initial mass, and λ is the decay coefficient. The decay coefficient can be computed from the constituent half-life ($t_{1/2}$) (the amount of time 50 % of the mass of the constituents to degrade) using the equation:

$$t_{1/2} = \frac{\ln 2}{\lambda} \qquad (5\text{-}3)$$

All simulations were performed with degradation. Tritium degrades at a half-life of 12.3 years. The equivalent a decay rate is 0.0564 day^{-1}.

Only numerical dispersion was considered in the transport analysis at the Site. No additional dispersion terms were included in the analysis. A limitation of the finite-difference scheme applied by MT3DMS is that numerical dispersion is inherent in the simulation results. Numerical dispersion is a function of the size of the mesh, the time step size, the hydrogeologic properties assigned in the model, and the simulated water levels. It should be noted that while numerical dispersion is an artifact of the solution process, there is no mathematical difference between physical and numerical dispersion. Application of the equations reported by Zheng and Bennett (1996) indicates that the numerical dispersivity is approximately one-half the modeled grid size (approximately 2.5 feet for this analysis).

5.3 Initial Conditions

The observed tritium concentrations in shallow sediments were used to initialize concentrations in the solute transport model (Figures 36 through 44). These observed concentration contours were interpolated for each model grid cell to achieve a numerical representation of the concentration distribution. All concentration in layer 10 (not shown) are below the remedial criteria (20,000 pCi/L). These contours were constructed use tritium data collected in March 2004 from both direct-push samples and monitoring wells. Values assigned were biased toward higher measured values to insure a conservative assessment of site conditions.

5.4 Solute Transport Scenarios

Three solute transport scenarios were evaluated the movement of tritium at the Site and each are described below. All transport simulations were initialized using the most recent observed tritium concentrations data. Each transport scenario was simulated over a 10 year period and is described as follows:

1. **Existing Conditions** – no active remediation was performed and the plume was assessed to determine, if and at what levels tritium would discharge at the site boundary

2. **Pilot Study Wells Pumping** – long term groundwater pumping using only the 4 wells selected for the groundwater pump and treatment pilot study.

3. **Full Scale Remediation** – long term groundwater pumping using a total of 8 wells.

The simulations generally show that the principal path of tritium is to migrate to the Delaware River. There is a slight downward flux from upgradient to down gradient due to precipitation recharge, varying from 3.5 ft/year at the water table to zero at the bottom of the formation. This gradient changes from neutral to upward as the groundwater nears the Delaware River.

Each of these scenarios was evaluated based upon their relative potential impacts on Delaware River. Results are available for each layer over the entire simulation period; however, a complete presentation of all this data for each simulation is too voluminous to be useful in summarizing results. Consequently, detailed plume maps were prepared of the maximum plume concentrations; plume data for all ten layers of the model were processed, and only the maximum concentration at any location in any model layer was presented. The results for each scenario are summarized in Figures 44 through 67.

5.4.1 Existing Conditions

Figures 44 through 46 show the predicted tritium concentration concentrations over the next 10 years if the plume is allowed to migrate with the ambient groundwater flow and there is no diffusion into inactive pores. This simulation is the worst case scenario predicting the fastest potential movement of groundwater and tritium. This simulation shows that concentrations in excess of the remedial goal (20,000 pCi/L) will reach the Delaware River approximately 5 years from now. This simulation also shows that the plume will be at concentrations greater than the remedial goal in 10 years. The change in total activity in the plume is presented as the lower line in Figure 50 showing a gradual decline in total activity over time.

Figures 47 through 49 show the predicted tritium concentration concentrations over the next 10 years if the plume is allowed to migrate with the ambient groundwater flow and there is diffusion into inactive pores. This simulation is the most likely case scenario predicting the movement of groundwater and tritium. This simulation shows that concentrations in excess of the remedial goal (20,000 pCi/L) will reach the Delaware River approximately 10 years from now. The time frame is consistent with the effective retardation factor of 1.75; diffusion into dead end pores will cause the plume to move approximately half as fast (1/1.75). This simulation also shows that the plume will be at concentrations greater than the remedial goal in 10 years. The change in total activity in the plume for this scenario is presented as the top line in Figure 50 showing a gradual decline in total activity over time. The total activity in the plume is computed to be between 5.62 and 9.84 curies depending on whether the effective porosity (0.2) or total porosity (0.35) is used in the calculation. The plot of total plume activity for this simulation is greater than the first analysis because of the increased pore spaces to retain tritium. The differences between the initial total activity in the respective plumes is the ratio of the total to the effective porosity (1.75 = 0.35/0.20)

5.4.2 Pilot Study

Figures 51 through 53 show the predicted tritium concentration concentrations over the next 10 years if the only pilot study wells are operated and there is no diffusion into inactive pores. This simulation shows that the pilot study wells will contain the tritium plume; groundwater concentrations in excess of 20,000 pCi/L will not reach the Delaware River. However, maximum concentrations will still exceed the remedial goal in 10 years. The change in total activity in the plume is presented as the lower line in Figure 57 showing an exponential reduction in total activity over time. At the end of ten years, approximately 90% of the plume has been removed

Figures 54 through 56 show the predicted tritium concentration concentrations over the next 10 years if only pilot study wells are operated and there is diffusion into inactive pores. This simulation is a more realistic prediction for this scenario. This simulation shows that the pilot study wells will contain the tritium plume; groundwater concentrations in excess of 20,000 pCi/L will not reach the Delaware River. However, maximum concentrations will still exceed the remedial goal in 10 years. The change in total activity in the plume is presented as the upper line in Figure 57 showing an exponential reduction in total activity over time. At the end of ten years, approximately 90% of the plume has been removed.

5.4.3 Full Scale Remediation

Figures 58 through 60 show the predicted tritium concentration concentrations over the next 10 years if additional remedial wells are operated and there is no diffusion into inactive pores. This simulation shows that the pilot study wells will contain the tritium plume; groundwater concentrations in excess of 20,000 pCi/L will not reach the Delaware River. However, maximum concentrations will still exceed the remedial goal in 10 years. The change in total activity in the plume is presented as the lower line in Figure 64 showing an exponential reduction in total activity over time. At the end of ten years, most of the plume has been removed

Figures 61 through 63 show the predicted tritium concentration concentrations over the next 10 years if additional wells are operated and there is diffusion into inactive pores. This simulation is a more realistic prediction for this scenario. This simulation shows that the pilot study wells will contain the tritium plume; groundwater concentrations in excess of 20,000 pCi/L will not reach the Delaware River. However, maximum concentrations will still exceed the remedial goal in 10 years. The change in total activity in the plume is presented as the upper line in Figure 64 showing an exponential reduction in total activity over time. At the end of ten years, approximately 95% of the plume has been removed.

5.5 Loading Calculations to Surface Water

In order to evaluate potential surface water impacts from groundwater seepage for each transport simulation, mass loading as a function of time was summarized directly from the MT3D output files (transport output) and the MODFLOW output (cell-by-cell water balance). The summary of these results is presented in Figures 65 through 67

The results from scenario one (Figure 65) show that no action is taken, the majority of tritium plume will eventually discharge to Delaware River, predicating the need for active remediation. Scenario 2 (Figure 66) shows that the 4 pilot study wells can

control the movement of tritium; however, as the pumping test is not designed or intended to be a full scale remedial system, it does not efficiently recover tritiated groundwater. After 10 years, the pilot study wells have extracted 7.22 curies of tritium, representing approximately 73 % of the current plume (conservatively assumed to be 9.84 curies, as noted in Section 5.4.1), and only 7.8 % of the 2004 tritium plume is still in the ground (the remaining balance is a function of natural decay). Scenario 3 (Scenario 67) shows that full scale remediation utilizing 9 recovery wells will be more efficient in the short term and better ensure on-site capture of groundwater as they extract more water, however, in the long term full scale remediation will on be marginally more effective at removing tritiated groundwater. After 10 years, the 9 recovery wells have extracted 7.83 curies of tritium, representing approximately 80 % of the conservative plume of 9.84 curies, and only 4.3 % of the 2004 tritium plume is still in the ground (similarly, the remaining balance is a function of natural decay).

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Table B-1. Summary of Groundwater Model Layers and Site Monitoring Wells

Modeling Layer	Top of Layer Elevation*	Bottom of Layer Elevation*
1	90.03	88
2	88	85
3	85	82
4	82	78
5	78	74
6	74	70
7	70	66
8	66	62
9	62	58
10	58	52

* Elevation in Plant Datum (ft)

Monitoring Wells	Modeling Layers	X-Site	Y-Site
Well AA	6,7,8	199541	230603
Well AB	8,9	199677	230623
Well AC	2,3,4	199745	230763
Well AD	8,9	199607	230684
Well AE	3,4,5	199845	230829
Well AF	8,9,10	199702	230491
Well AG-S	3,4,5	199508	230496
Well AG-S/D	7,8	199508	230497
Well AH-S	2,3,4	199599	230445
Well AH-S/D	6,7,8	199599	230445
Well AI	2,3,4	199552	230801
Well AJ	3,4,5,6,7,8	199665	230670
Well AL	3,4,5	199806	230594
WELL AM	2,3,4	199682	230781
WELL M	1,2,3	199541	230847
WELL N	1,2,3	199661	230777
WELL O	1,2,3	199843	230806
WELL R	1,2,3	199640	230906
Well S	6,7,8	199613	230711
Well W	6,7,8	199450	230777
Well Y	6,7	199343	230771
Well Z	6,7,8	199399	230681

Table B-2. Summary of Observed and Simulated Water Levels, and Calculated Residuals

Monitoring Well	Model Location			Water Levels		Model
	Layer	Row	Column	Computed	Observed	Residual
Well AA	6	170	79	91.522	91.19	0.332
Well AA	7	170	79	91.519	91.19	0.329
Well AA	8	170	79	91.519	91.19	0.329
Well AB	8	145	90	91.74	91.79	-0.05
Well AB	9	145	90	91.737	91.79	-0.053
Well AC	2	118	74	93.181	93.56	-0.379
Well AC	3	118	74	93.111	93.56	-0.449
Well AC	4	118	74	93.065	93.56	-0.495
Well AD	8	150	72	91.69	91.48	0.21
Well AD	9	150	72	91.691	91.48	0.211
Well AE	3	94	73	94.621	94.43	0.191
Well AE	4	94	73	94.576	94.43	0.146
Well AE	5	94	73	94.54	94.43	0.11
Well AF	8	155	115	91.513	91.59	-0.077
Well AF	9	155	115	91.516	91.59	-0.074
Well AF	10	155	115	91.52	91.59	-0.07
Well AG-S	3	187	93	90.972	91.09	-0.118
Well AG-S	4	187	93	90.966	91.09	-0.124
Well AG-S	5	187	93	90.963	91.09	-0.127
Well AH-S	2	177	111	91.098	90.91	0.188
Well AH-S	3	177	111	91.083	90.91	0.173
Well AH-S	4	177	111	91.063	90.91	0.153
Well AH-S/	6	177	111	91.008	91.14	-0.132
Well AH-S/	7	177	111	90.988	91.14	-0.152
Well AH-S/	8	177	111	90.977	91.14	-0.163
Well AI	2	147	46	92.27	92.29	-0.02
Well AI	3	147	46	92.201	92.29	-0.089
Well AI	4	147	46	92.156	92.29	-0.134
Well AJ	3	142	81	91.818	91.63	0.188
Well AJ	4	142	81	91.807	91.63	0.177
Well AJ	5	142	81	91.794	91.63	0.164
Well AJ	6	142	81	91.783	91.63	0.153
Well AJ	7	142	81	91.775	91.63	0.145
Well AJ	8	142	81	91.769	91.63	0.139
Well AL	3	126	109	92.557	93.71	-1.153
Well AL	4	126	109	92.292	93.71	-1.418
Well AL	5	126	109	92.094	93.71	-1.616
WELL AM	2	127	64	92.787	92.73	0.057
WELL AM	3	127	64	92.722	92.73	-0.008
WELL AM	4	127	64	92.68	92.73	-0.05
WELL N	1	131	62	92.819	92.35	0.469
WELL N	2	131	62	92.691	92.35	0.341
WELL N	3	131	62	92.624	92.35	0.274

Table B-2(continued). Summary of Observed and Simulated Water Levels, and Calculated Residuals

Monitoring Well	Model Location			Water Levels		Model
	Layer	Row	Column	Computed	Observed	Residual*
WELL O	1	97	77	94.644	94.41	0.234
WELL O	2	97	77	94.571	94.41	0.161
WELL O	3	97	77	94.508	94.41	0.098
WELL R	1	121	38	94.895	94.84	0.055
WELL R	2	121	38	94.877	94.84	0.037
WELL R	3	121	38	94.869	94.84	0.029
Well S	6	146	68	91.712	91.72	-0.008
Well S	7	146	68	91.706	91.72	-0.014
Well S	8	146	68	91.703	91.72	-0.017
Well W	6	166	39	91.331	91.82	-0.489
Well W	7	166	39	91.326	91.82	-0.494
Well W	8	166	39	91.324	91.82	-0.496
Well Y	6	185	29	91.064	91.19	-0.126
Well Y	7	185	29	91.057	91.19	-0.133
Well Z	6	185	50	91.163	91.24	-0.077
Well Z	7	185	50	91.157	91.24	-0.083
Well Z	8	185	50	91.153	91.24	-0.087
WELL M2	3	144	38	92.847	93.64	-0.793
Well AG-S/	8	187	93	90.997	90.3	0.697
Well AG-S/	7	187	93	90.991	90.3	0.691
WELL M	1	144	38	93.073	93.64	-0.567
WELL M	2	144	38	92.924	93.64	-0.716

* Residual = Simulated Water Level - Observed Water Level

Total Targets	65	
Minimum	-1.616	ft
Maximum	0.697	ft
Mean	-0.07	ft
Median	-0.017	
Standard Deviation	0.411	
Redidual Sum of Squares	11.156	ft^2

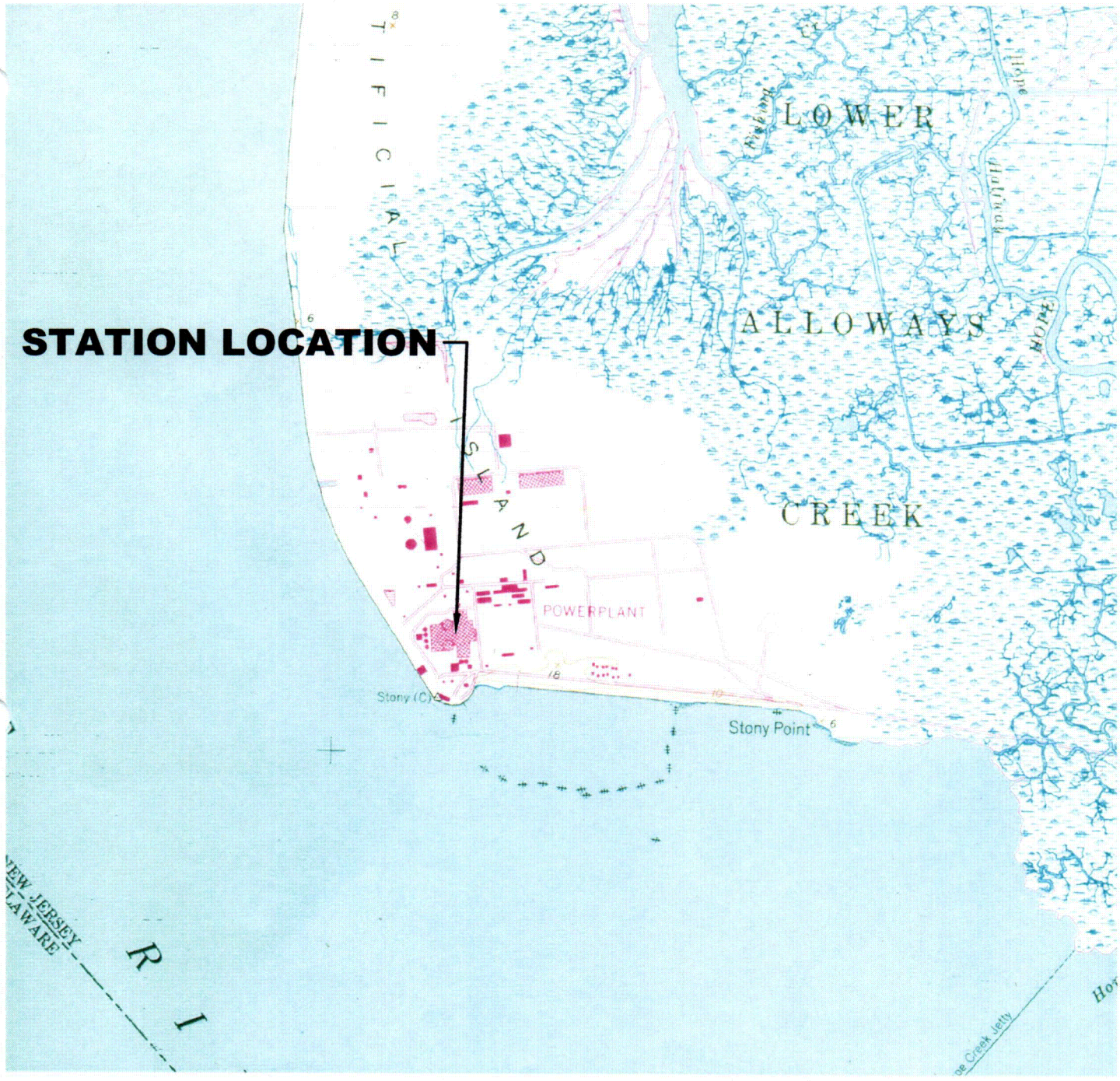
Table B-3. Summary of Groundwater Extraction Rates

Pilot Study Well

Well ID	Extraction Rates (gpm)
Well AB	-2.00
Well AC	-0.12
Well AD	-0.25
Well AI	-0.12

Full-Scale Remediation Wells

Well ID	Extraction Rates (gpm)
Well AB	-2.00
Well AD	-0.25
Well AI	-0.12
Well AJ	-0.50
Well AM	-0.05
Well AN	-0.12
Well AQ	-0.50
Well AS	-0.50
Well S	-0.50



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

MN GN

10 ½° 187 MILS 0°21' 6 MIL

UTM GRID AND 1981 MAGNETIC NORTH

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

ARCADIS

DRAWN	DATE	PROJECT MANAGER	DEPARTMENT MANAGER
M. WASILEWSKI	5/25/05	P. MILIONIS	D. FULTON
		LEAD DESIGN PROF. S. POTTER	CHECKED B. PIERCE

SITE MAP

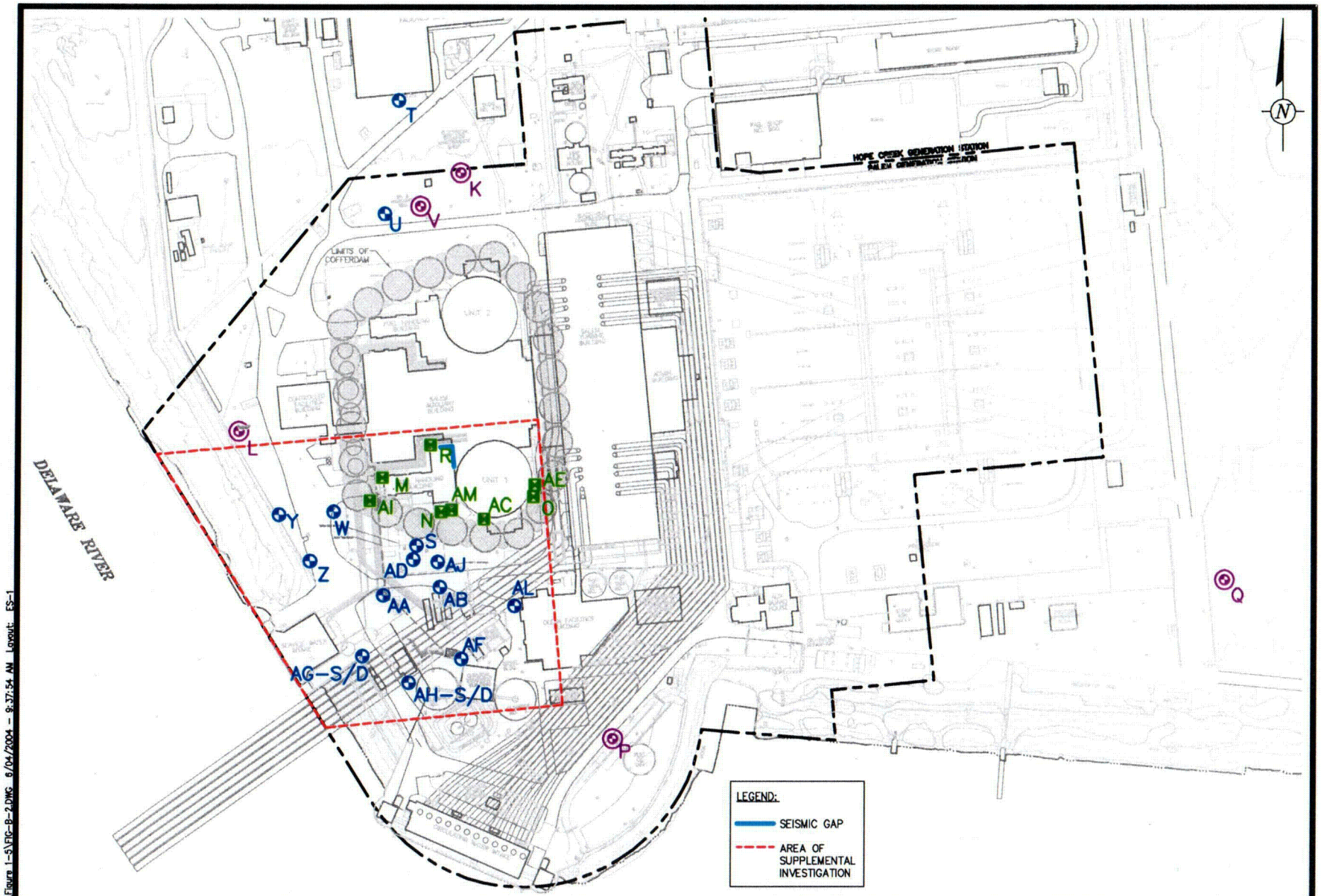
PSEG NUCLEAR, LLC
SALEM GENERATING STATION

PROJECT NUMBER: NP000571.0004

FIGURE: B-1

C:\PSEG\Model\Report\Figures\Figure 1-5\FIG-B-1 SITE MAP.DWG 5/28/2004 - 1:43:38 PM Layout: 8.5x11 H

C04



C:\PSEG\Model\Report\Figures\Figure 1-5\FIG-B-2.DWG 8/04/2004 - 9:37:54 AM Layout: FS-1

0 250
SCALE: 1"=250'

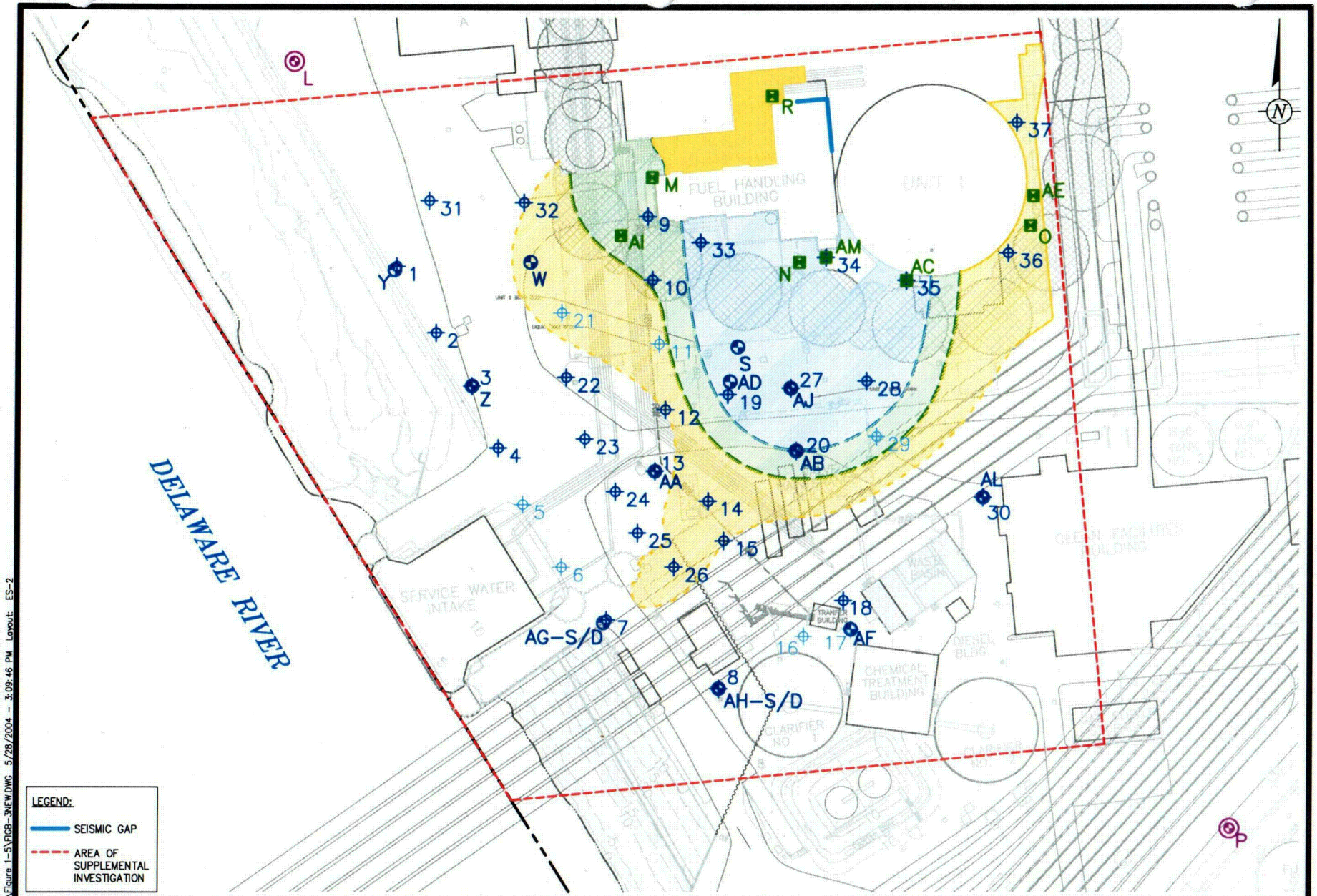
ARCADIS

DRAWN	DATE	PROJECT MANAGER	DEPARTMENT MANAGER
M. WASILEWSKI	9/16/03	P. MILIONIS	D. FULTON
		LEAD DESIGN PROF. S. POTTER	CHECKED B. PIERCE

MONITORING WELL NETWORK FOR THE REMEDIAL INVESTIGATION
PSEG NUCLEAR, LLC
SALEM GENERATING STATION
ARTIFICIAL ISLAND
HANCOCK'S BRIDGE, NEW JERSEY

PROJECT NUMBER	DRAWING NUMBER
NP000571.0004	B-2

C05



0 100
SCALE: 1"=100'

ARCADIS

DRAWN: M. WASILEWSKI	DATE: 9/16/03	PROJECT MANAGER: P. MILIONIS	DEPARTMENT MANAGER: D. FULTON
		LEAD DESIGN PROF.: S. POTTER	CHECKED: B. PIERCE

Extent of Tritiated Groundwater

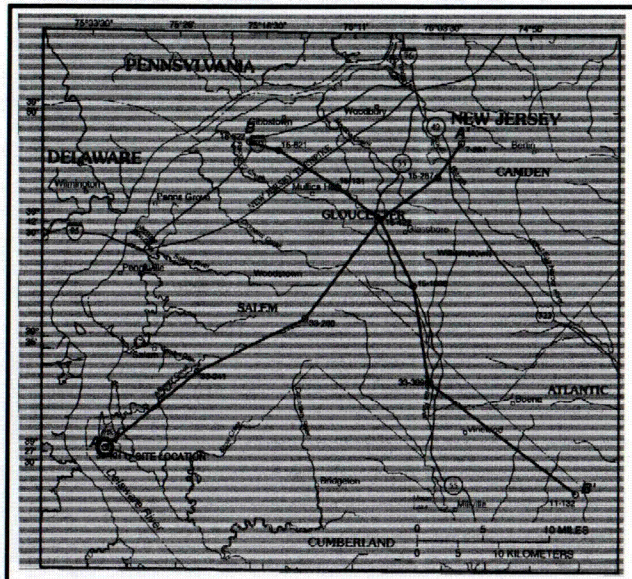
PSEG NUCLEAR, LLC
SALEM GENERATING STATION

PROJECT NUMBER: NP000571.0004

DRAWING NUMBER: B-3

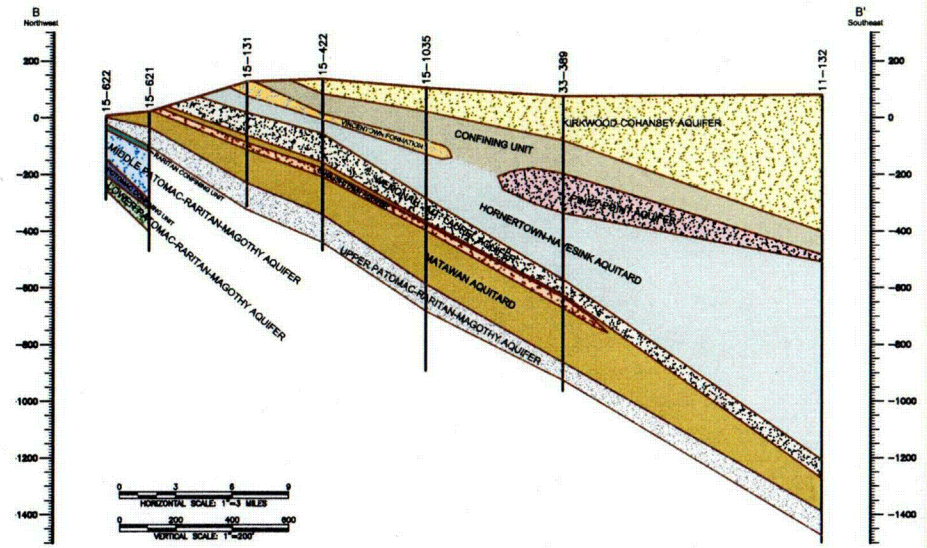
C:\PSEG\Model\Report\Figures\Figure 1-5\FIGB-3NEW.DWG 5/28/2004 - 3:09:46 PM Layout: ES-2

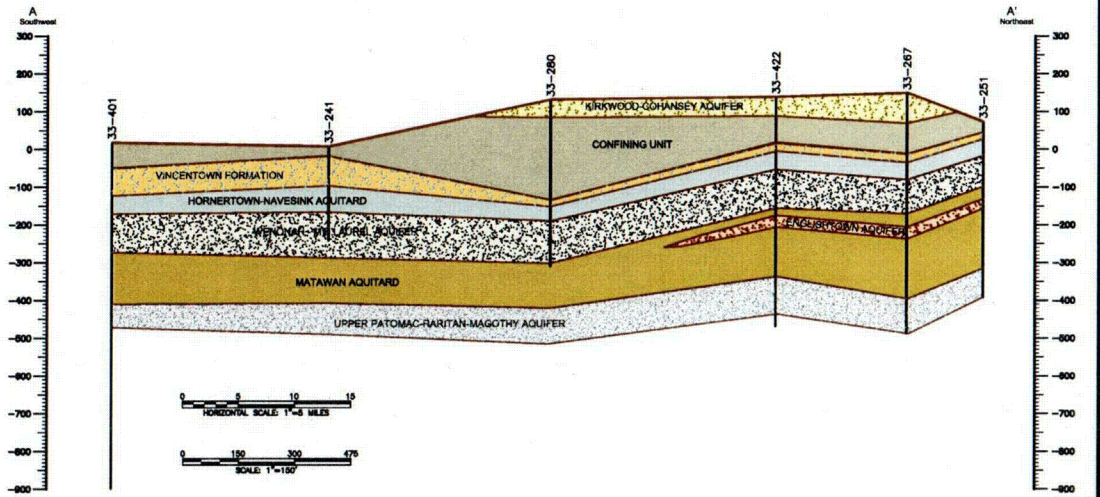
COG



SOURCE:

CAULLER, STEPHEN J., GLEN B. CARLETON, MELISSA J. STORCH, HYDROGEOLOGY OF, WATER WITHDRAWAL, FLOW, AND WATER LEVELS AND CHLORIDE CONCENTRATIONS IN THE MAJOR CONFINED PLAIN AQUIFERS OF GLOUCESTER AND SALEM COUNTIES, NEW JERSEY: UNITED STATES GEOLOGIC SURVEY WATER-RESOURCES INVESTIGATION REPORT 98-4136, 1998.





NO.	DATE	REVISION DESCRIPTION	BY

PSEG NUCLEAR, LLC
SALEM GENERATING STATION

ARTIFICIAL ISLAND
HANCOCK'S BRIDGE, NEW JERSEY

SITE HYDROSTRATIGRAPHY

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

PROJECT MANAGER	DEPARTMENT MANAGER
P. MILIONIS	D. FULTON
LEAD DESIGN PROF.	CHECKED
S. POTTER	B. PIERCE
DRAWN	DATE
M. WASILEWSKI	2/27/04
PROJECT NUMBER	FIGURE
NP000571.0004	B-4

C07

G:\APROJECT\PSE&G\Salem\NP000571.0004 - Remedial Actions\Task 05 - Groundwater Modeling\Report\Figures\Figure 1-5\FIG-B-5 ELEVATION MAP OF THE TOP OF THEKIRKWOOD FORMATION.dwg, 13/ 7/2004 7:23pm

0 150 300
SCALE: 1"=150'

NO.	DATE	REVISION DESCRIPTION	BY

ARCADIS
6 Terry Drive
Suite 300 , Newtown, PA 18940
Tel: 267/685-1600 Fax: 267/685-1601

PSEG NUCLEAR, LLC
SALEM GENERATING STATION

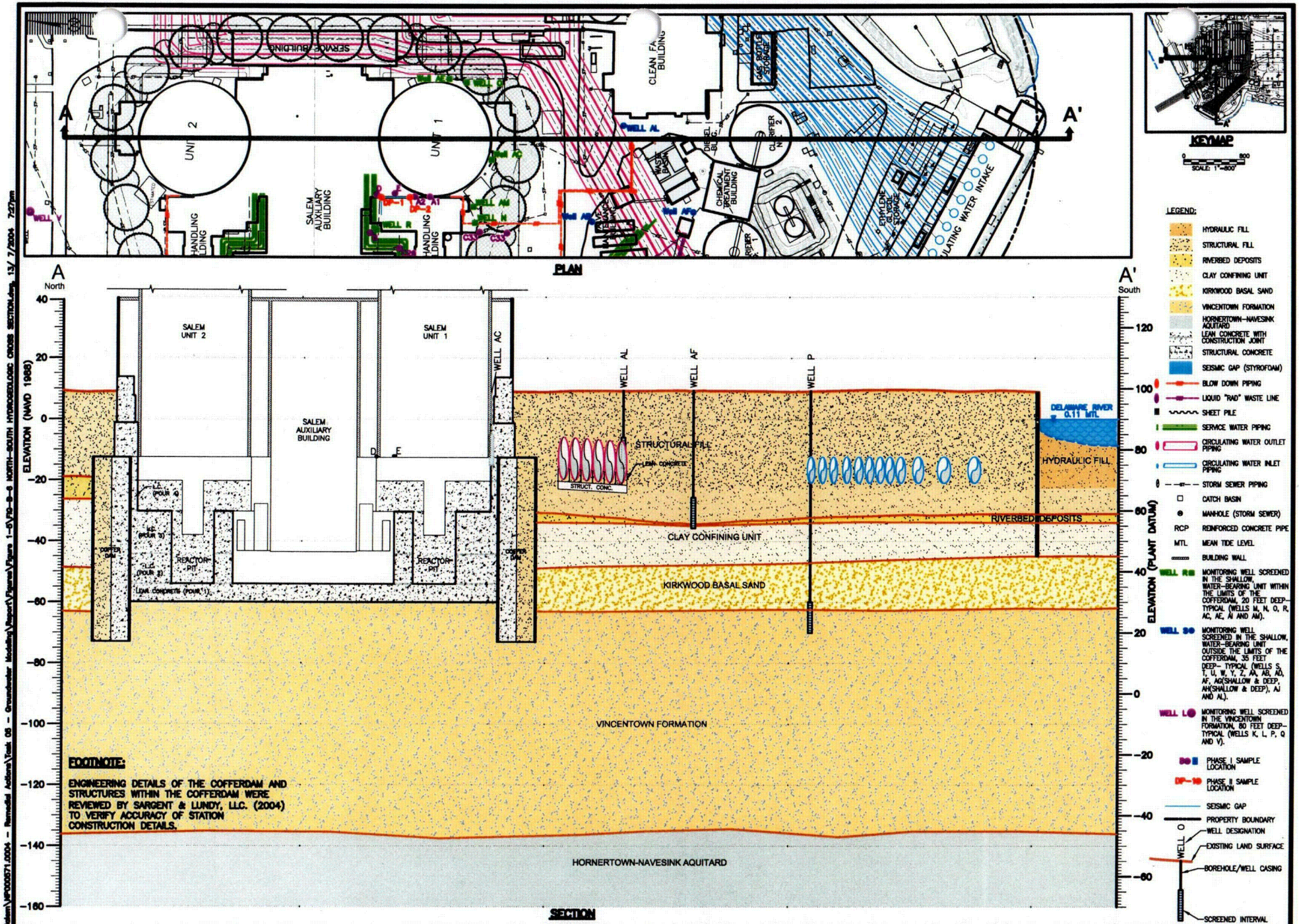
ARTIFICIAL ISLAND
HANCOCK'S BRIDGE, NEW JERSEY

DRAWN	DATE	PROJECT MANAGER	DEPARTMENT MANAGER
M. WHELEHAN	8/25/04	P. MILIONIS	D. FULTON
		LEAD DESIGN PROF.	CHECKED
		B. POTTER	B. PIERCE

ELEVATION MAP OF THE TOP OF THE CLAY CONFINING UNIT

PROJECT NUMBER: NP000571.0004
FIGURE: B-5

C08



VERTICAL SCALE: 1"=20'
HORIZONTAL SCALE: 1"=80'

NO.	DATE	REVISION DESCRIPTION	BY
1	6/8/05	CLIENT SUBMITTAL	MW

ARCADIS
6 Terry Drive
Suite 300 , Newtown, PA 18940
Tel: 267/685-1600 Fax: 267/685-1601

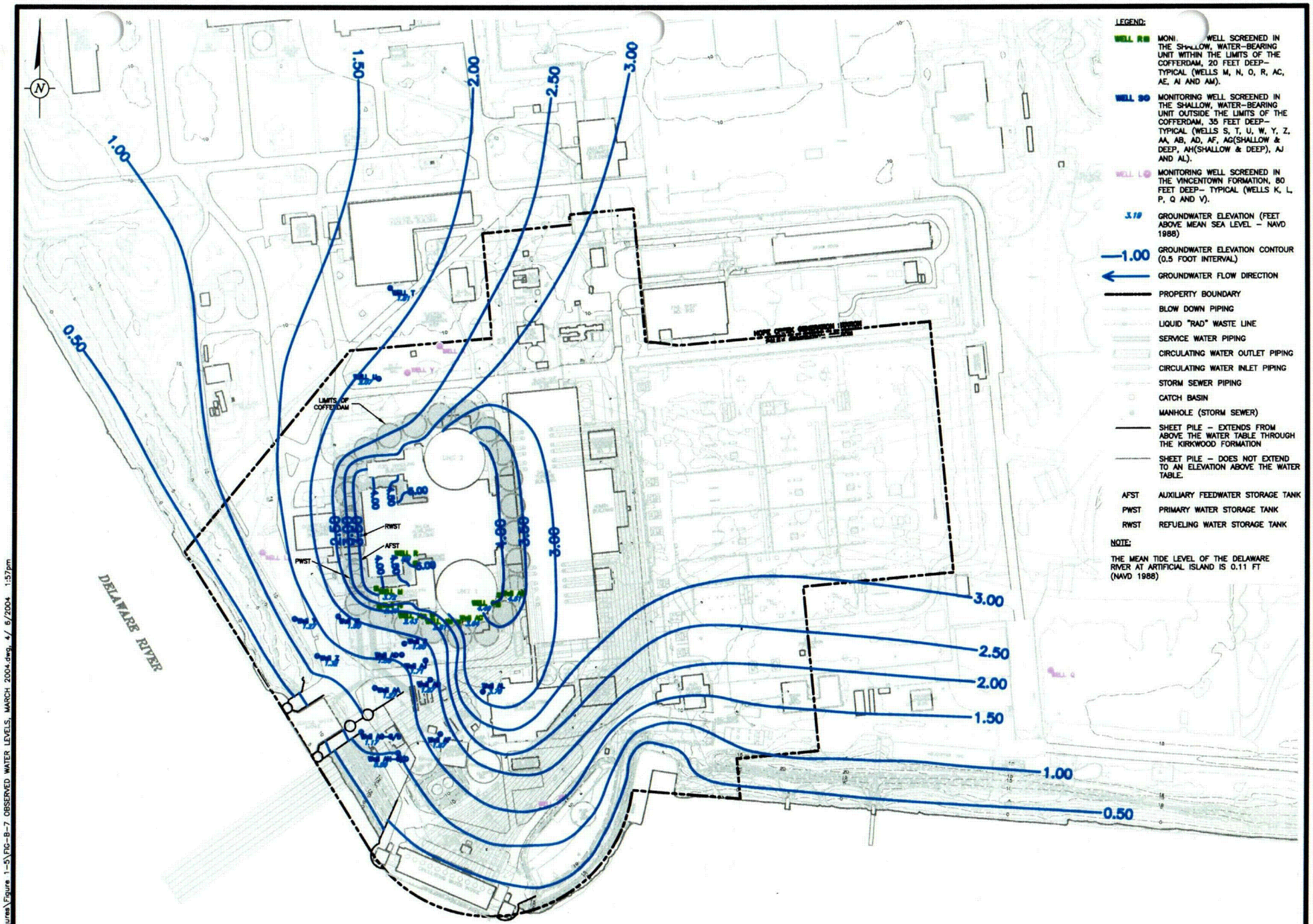
PSEG NUCLEAR, LLC
SALEM GENERATING STATION
ARTIFICIAL ISLAND
HANCOCK'S BRIDGE, NEW JERSEY

DRAWN	DATE	PROJECT MANAGER	DEPARTMENT MANAGER
M. WARLEMAN	5/25/04	P. MILIONIS	D. FULTON
		LEAD DESIGN PROF. S. POTTER	CHECKED B. PIERCE

NORTH-SOUTH HYDROGEOLOGIC CROSS SECTION (A-A')

PROJECT NUMBER: NP000571.0004
FIGURE: B-6

C09



C:\PSEG\Model\Report\Figures\Figure 1-5\FIG-B-7 OBSERVED WATER LEVELS, MARCH 2004.dwg, 4/ 6/2004 1:57pm

0 150 300
SCALE: 1"=150'

NO.	DATE	REVISION DESCRIPTION	BY

ARCADIS
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

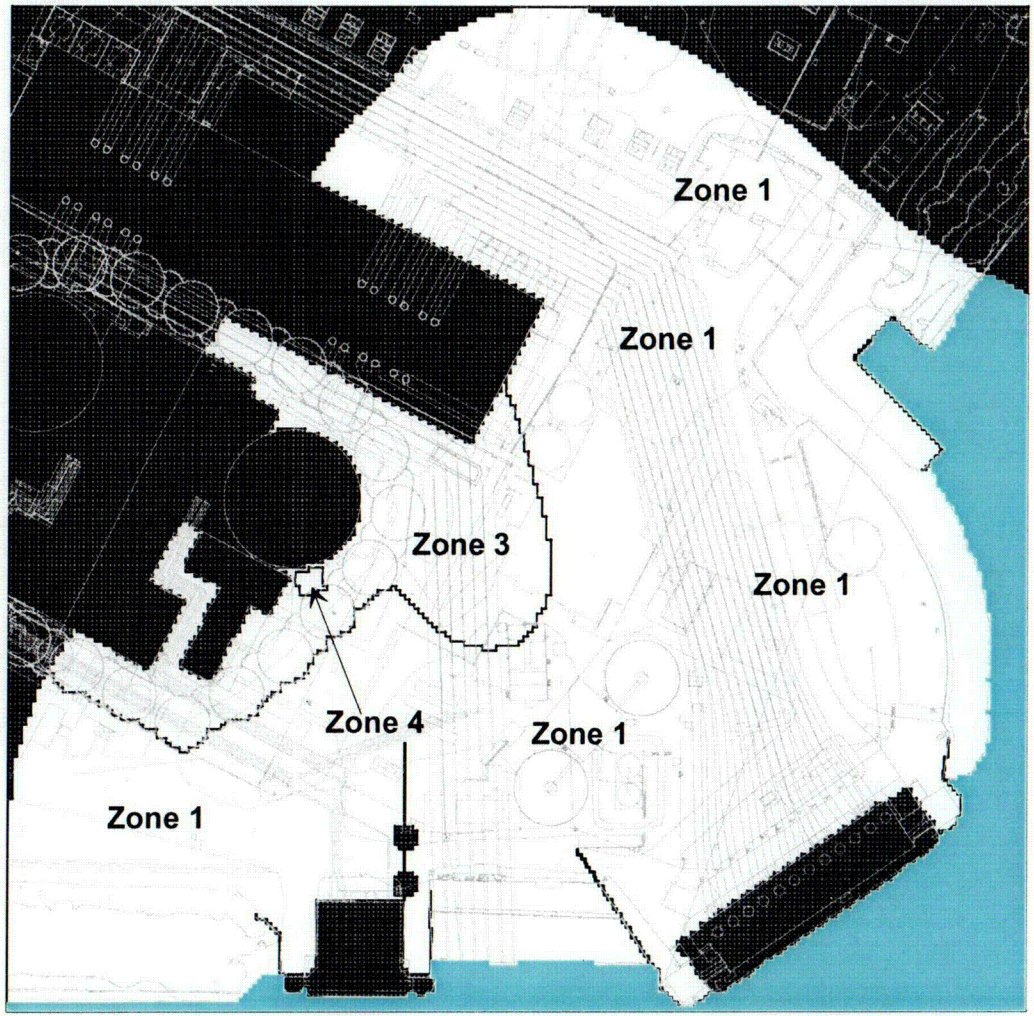
DRAWN	DATE	PROJECT MANAGER	DEPARTMENT MANAGER
M. WHELEHAN	5/25/04	P. MILIONIS	B. FULTON
		LEAD DESIGN PROF.	CHECKED
		S. POTTER	B. PIERCE

OBSERVED WATER LEVELS
MARCH 2004

PROJECT NUMBER: NP000571.0004

FIGURE: B-7

DWG DATE:	5/14/04	PRJCT NO.:	NP000571.0004.00005	FILE NO.:	Figure08.srf	CHECKED:	STP	APPROVED:	PM	DRAFTER:	SW



Legend

- No Flow Cells
- Constant Head Cells
- Sheet Pile

Hydraulic Conductivity Zonation

	Kh/Kv (ft/day)
Zone 1	6.5/0.65
Zone 2	2.5/0.25
Zone 3	0.3974/0.03974
Zone 4	0.125/0.0125

0ft 200ft 400ft

Scale: 1"=200'

ARCADIS

Model Domain, Boundary Conditions, and Hydraulic Conductivity Zonation - Model Layer 1

PSEG NUCLEAR, LLC
Salem Generating Station

FIGURE

B-8

C11

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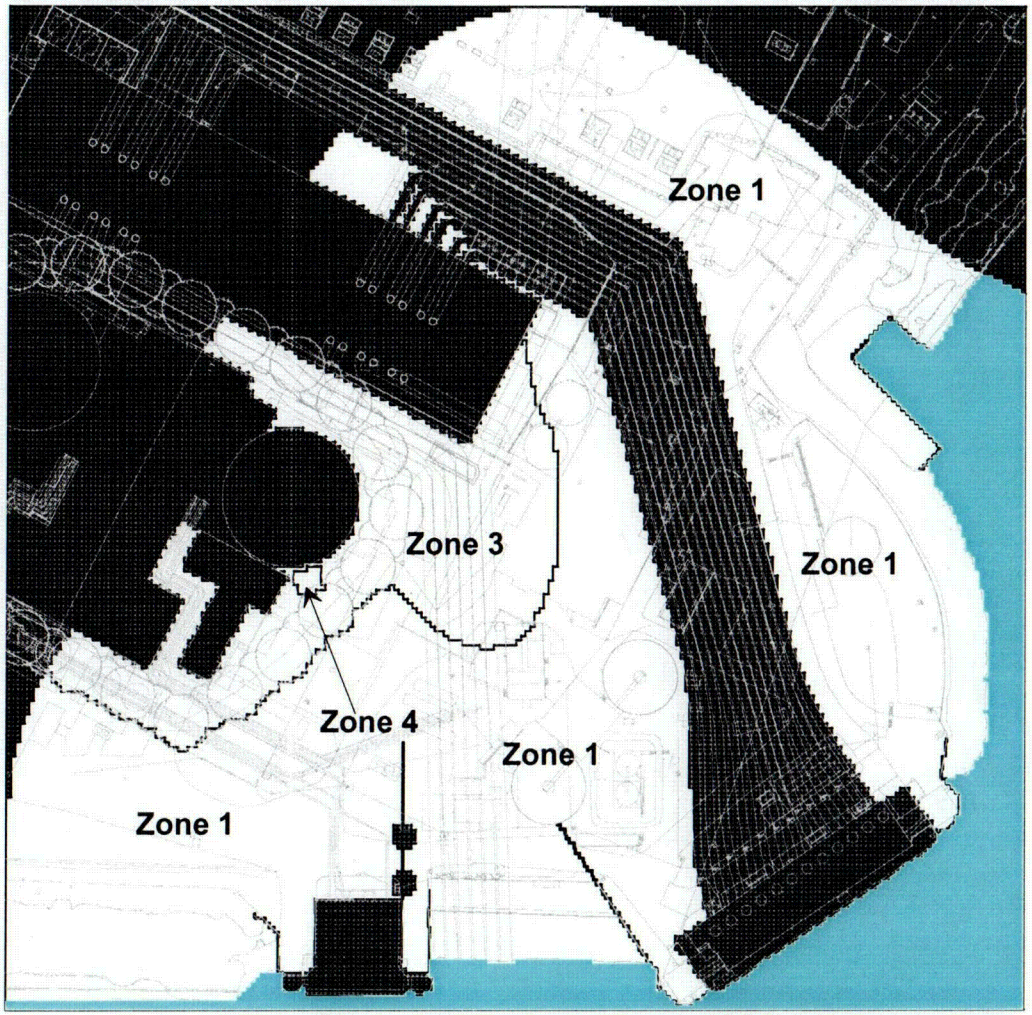

Legend

- No Flow Cells
- Constant Head Cells
- Sheet Pile

Hydraulic Conductivity Zonation

	Kh/Kv (ft/day)
Zone 1	6.5/0.65
Zone 2	2.5/0.25
Zone 3	0.3974/0.03974
Zone 4	0.125/0.0125

0ft 200ft 400ft

Scale: 1"=200'

ARCADIS

Model Domain, Boundary Conditions, and Hydraulic Conductivity Zonation - Model Layer 2

PSEG NUCLEAR, LLC
Salem Generating Station

FIGURE
B-9

C12

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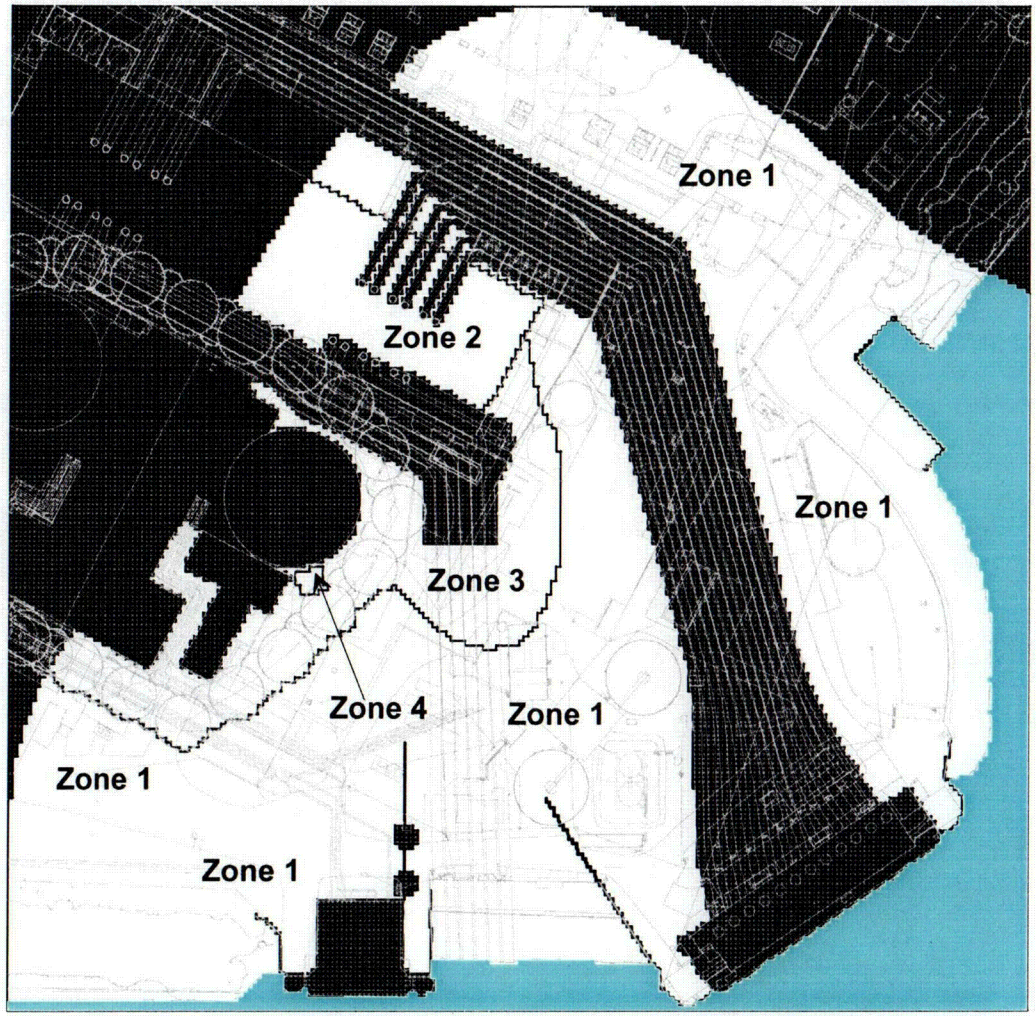


Legend

- No Flow Cells
- Constant Head Cells
- Sheet Pile

Hydraulic Conductivity Zonation

	Kh/Kv (ft/day)
Zone 1	6.5/0.65
Zone 2	2.5/0.25
Zone 3	0.3974/0.03974
Zone 4	0.125/0.0125

0ft 200ft 400ft

Scale: 1"=200'

ARCADIS

Model Domain, Boundary Conditions, and Hydraulic Conductivity Zonation - Model Layer 3

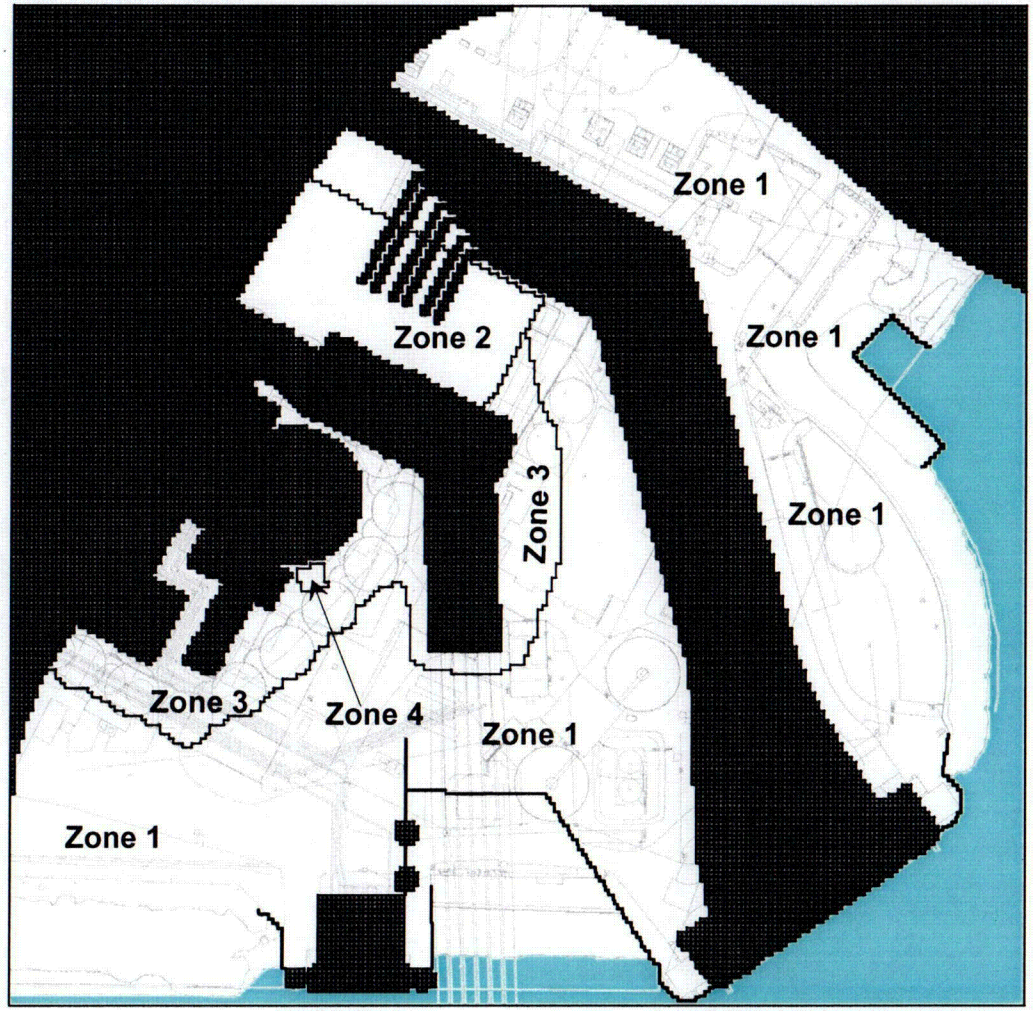
PSEG NUCLEAR, LLC
Salem Generating Station

FIGURE

B-10

C13

DWG DATE: 5/14/04	PRJCT NO.: NP000571.0004.00005	FILE NO.: Figure11.srf	CHECKED: STP	APPROVED: PM	DRAFTER: SW



Legend

- No Flow Cells
- Constant Head Cells
- Sheet Pile

Hydraulic Conductivity Zonation

	Kh/Kv (ft/day)
Zone 1	6.5/0.65
Zone 2	2.5/0.25
Zone 3	0.3974/0.03974
Zone 4	0.125/0.0125

Scale: 1"=200'

ARCADIS

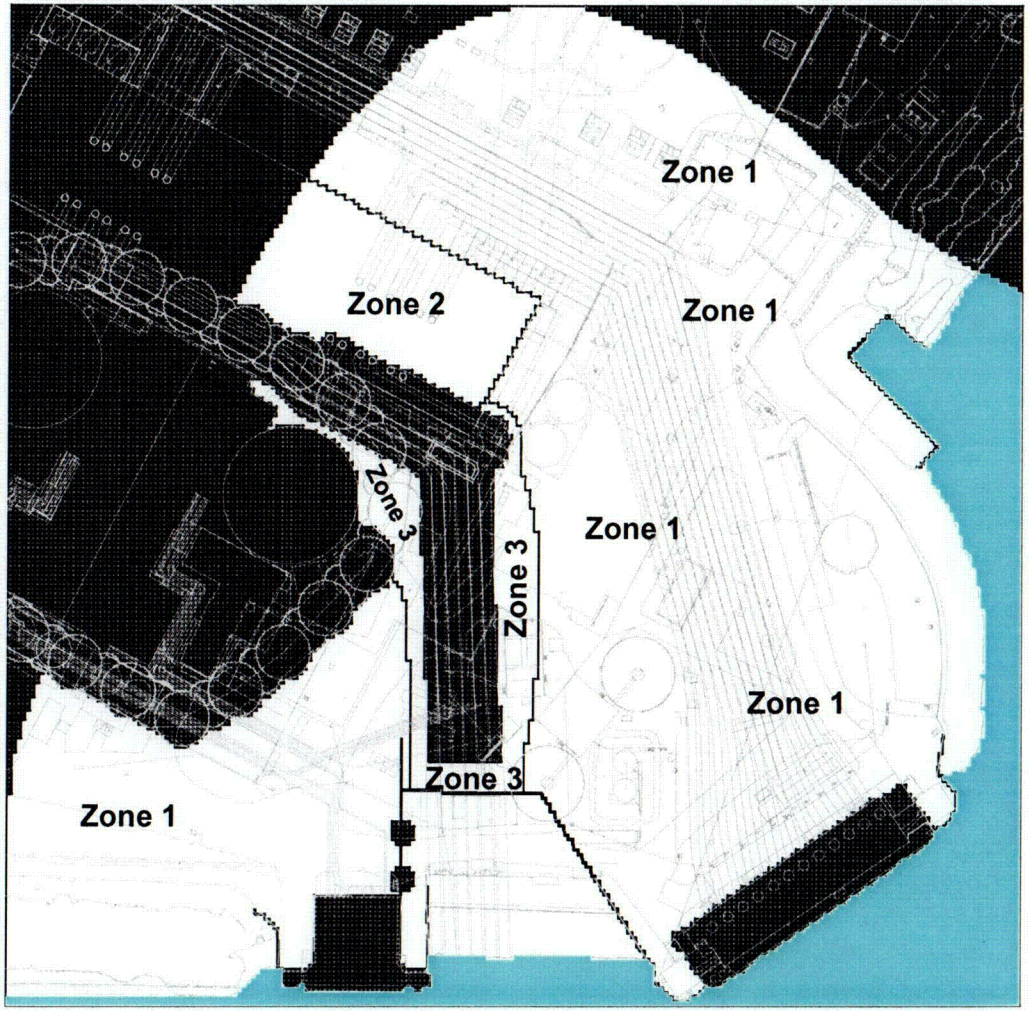
Model Domain, Boundary Conditions, and Hydraulic Conductivity Zonation - Model Layer 4

PSEG NUCLEAR, LLC
Salem Generating Station

FIGURE

B-11

DWG DATE:	5/14/04	PRJCT NO.:	NP000571.0004.00005	FILE NO.:	Figure12.srf	CHECKED:	STP	APPROVED:	PM	DRAFTER:	SW



Legend

- No Flow Cells
- Constant Head Cells
- Sheet Pile

Hydraulic Conductivity Zonation

	Kh/Kv (ft/day)
Zone 1	6.5/0.65
Zone 2	2.5/0.25
Zone 3	0.3974/0.03974
Zone 4	0.125/0.0125

0ft 200ft 400ft

Scale: 1"=200'

ARCADIS

Model Domain, Boundary Conditions, and Hydraulic Conductivity Zonation - Model Layer 5

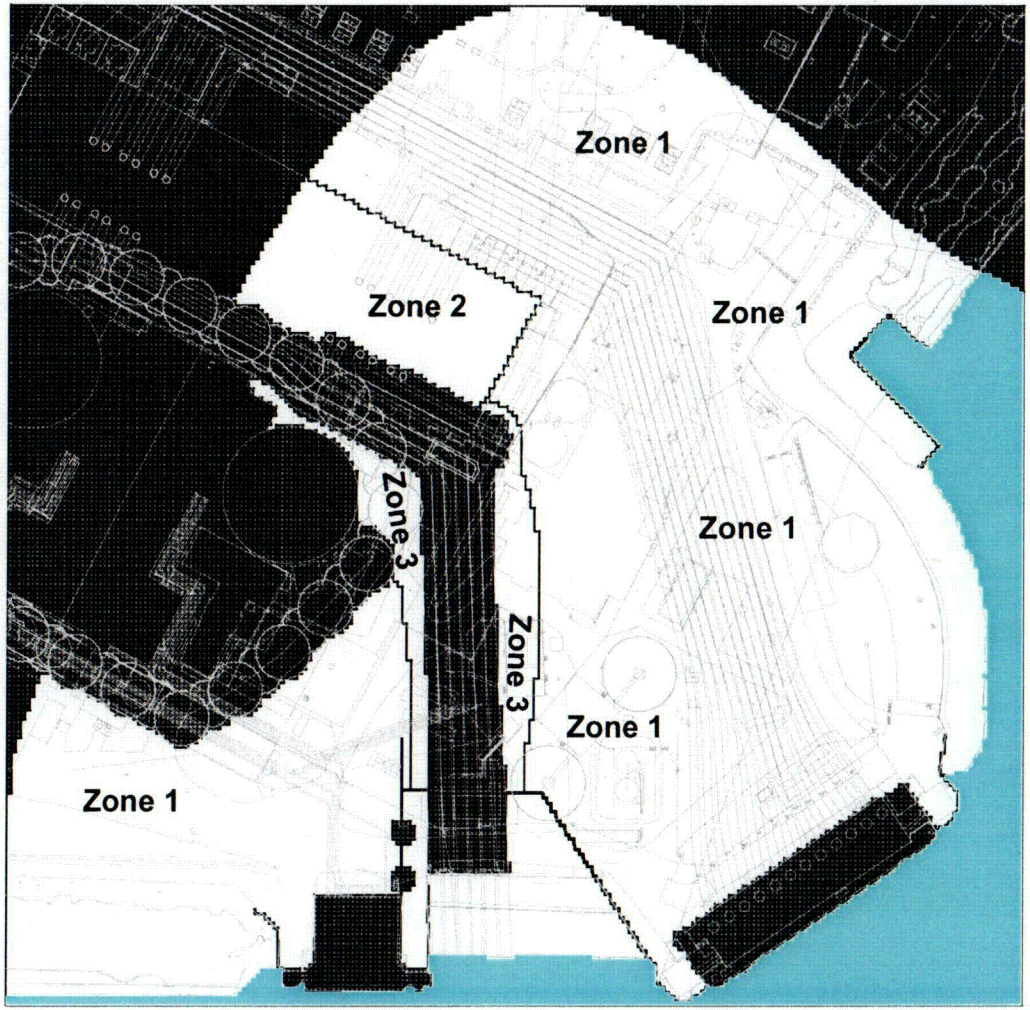
PSEG NUCLEAR, LLC
Salem Generating Station

FIGURE

B-12

C15

DWG DATE:	5/14/04	PRJCT NO.:	NP000571.0004.00005	FILE NO.:	Figure13.srf	CHECKED:	STP	APPROVED:	PM	DRAFTER:	SW



Legend

- No Flow Cells
- Constant Head Cells
- Sheet Pile

Hydraulic Conductivity Zonation

	Kh/Kv (ft/day)
Zone 1	6.5/0.65
Zone 2	2.5/0.25
Zone 3	0.3974/0.03974
Zone 4	0.125/0.0125

0ft 200ft 400ft

Scale: 1"=200'

ARCADIS

Model Domain, Boundary Conditions, and Hydraulic Conductivity Zonation - Model Layer 6

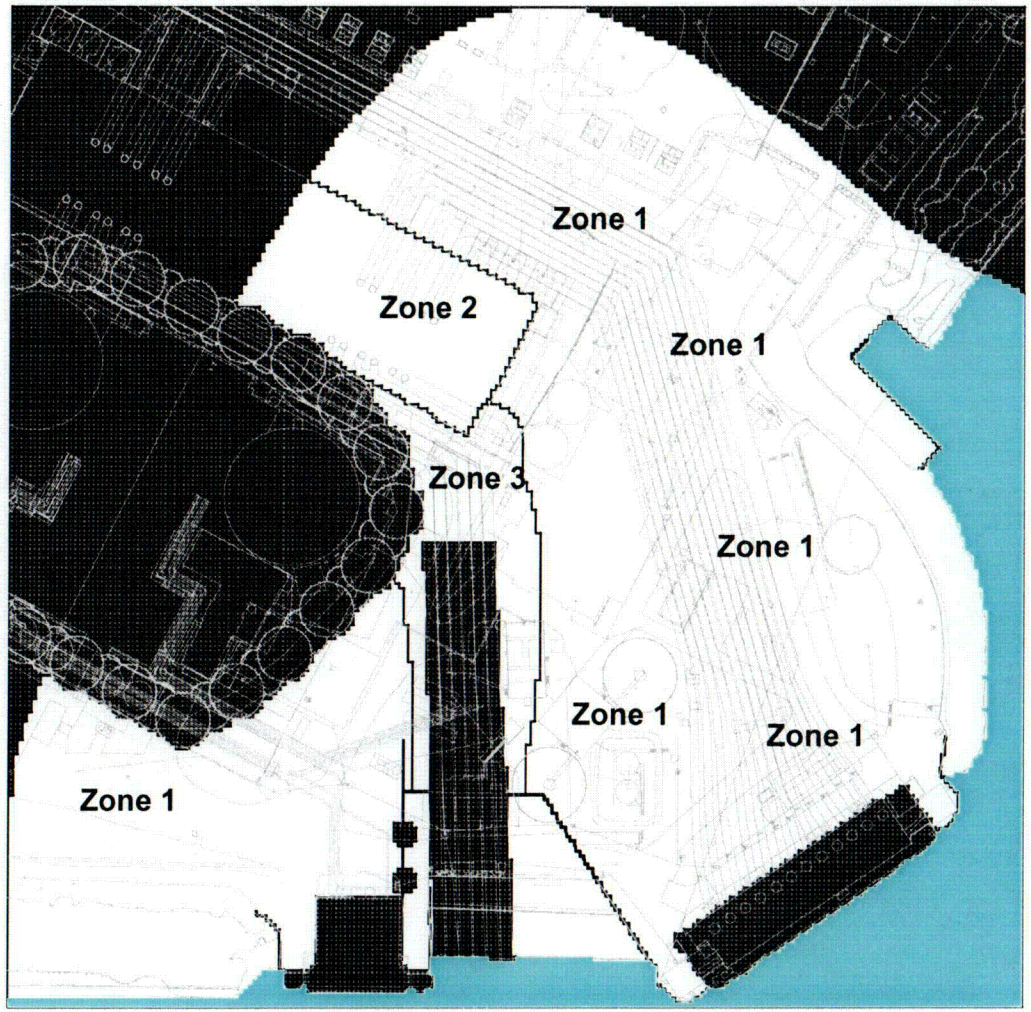
PSEG NUCLEAR, LLC
Salem Generating Station

FIGURE

B-13

C16

DWG DATE: 5/14/04	PRJCT NO.: NP000571.0004.00005	FILE NO.: Figure14.srf	CHECKED: STP	APPROVED: PM	DRAFTER: SW



Legend

- No Flow Cells
- Constant Head Cells
- Sheet Pile

Hydraulic Conductivity Zonation

	Kh/Kv (ft/day)
Zone 1	6.5/0.65
Zone 2	2.5/0.25
Zone 3	0.3974/0.03974
Zone 4	0.125/0.0125

0ft 200ft 400ft

Scale: 1"=200'

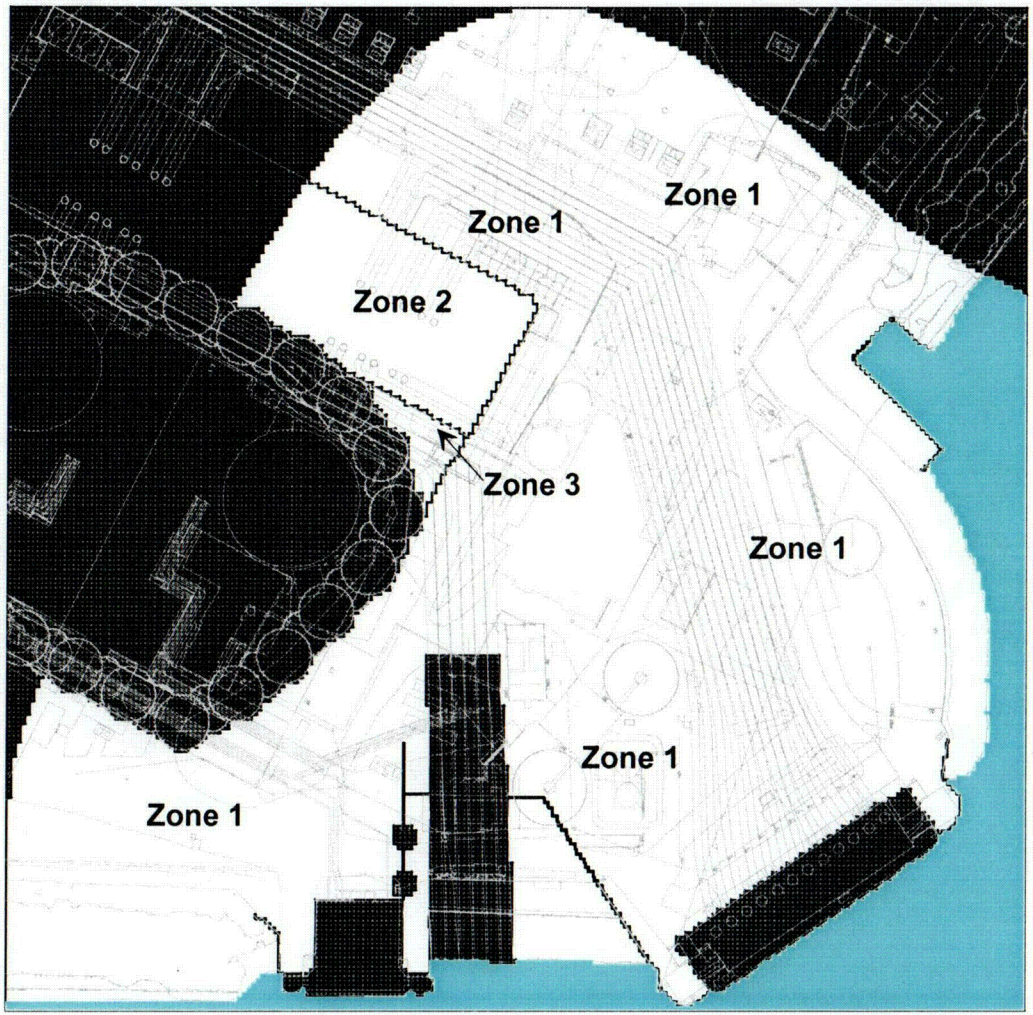
ARCADIS

Model Domain, Boundary Conditions, and Hydraulic Conductivity Zonation - Model Layer 7

PSEG NUCLEAR, LLC
Salem Generating Station

FIGURE
B-14

DWG DATE:	5/14/04	PRJCT NO.:	NP000571.0004.00005	FILE NO.:	Figure15.srf	CHECKED:	STP	APPROVED:	PM	DRAFTER:	SW



Legend

- No Flow Cells
- Constant Head Cells
- Sheet Pile

Hydraulic Conductivity Zonation

	Kh/Kv (ft/day)
Zone 1	6.5/0.65
Zone 2	2.5/0.25
Zone 3	0.3974/0.03974
Zone 4	0.125/0.0125

0ft 200ft 400ft

Scale: 1"=200'

ARCADIS

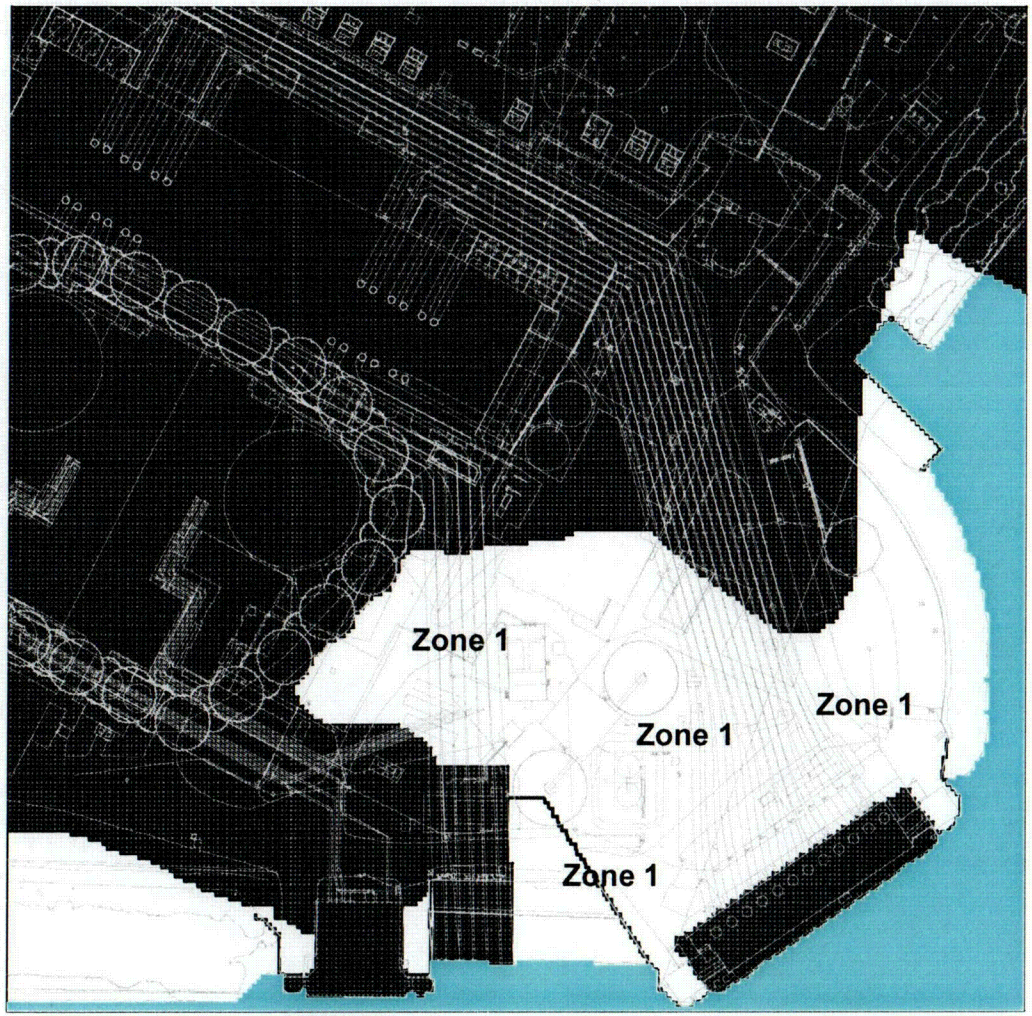
Model Domain, Boundary Conditions, and Hydraulic Conductivity Zonation - Model Layer 8

PSEG NUCLEAR, LLC
Salem Generating Station

FIGURE
B-15

C18

DWG DATE:	5/14/04	PRJCT NO.: NP000571.0004.00005	FILE NO.:	Figure16.srf	CHECKED:	STP	APPROVED:	PM	DRAFTER:	SW



Legend

- No Flow Cells
- Constant Head Cells
- Sheet Pile

Hydraulic Conductivity Zonation

	Kh/Kv (ft/day)
Zone 1	6.5/0.65
Zone 2	2.5/0.25
Zone 3	0.3974/0.03974
Zone 4	0.125/0.0125

0ft 200ft 400ft

Scale: 1"=200'

ARCADIS

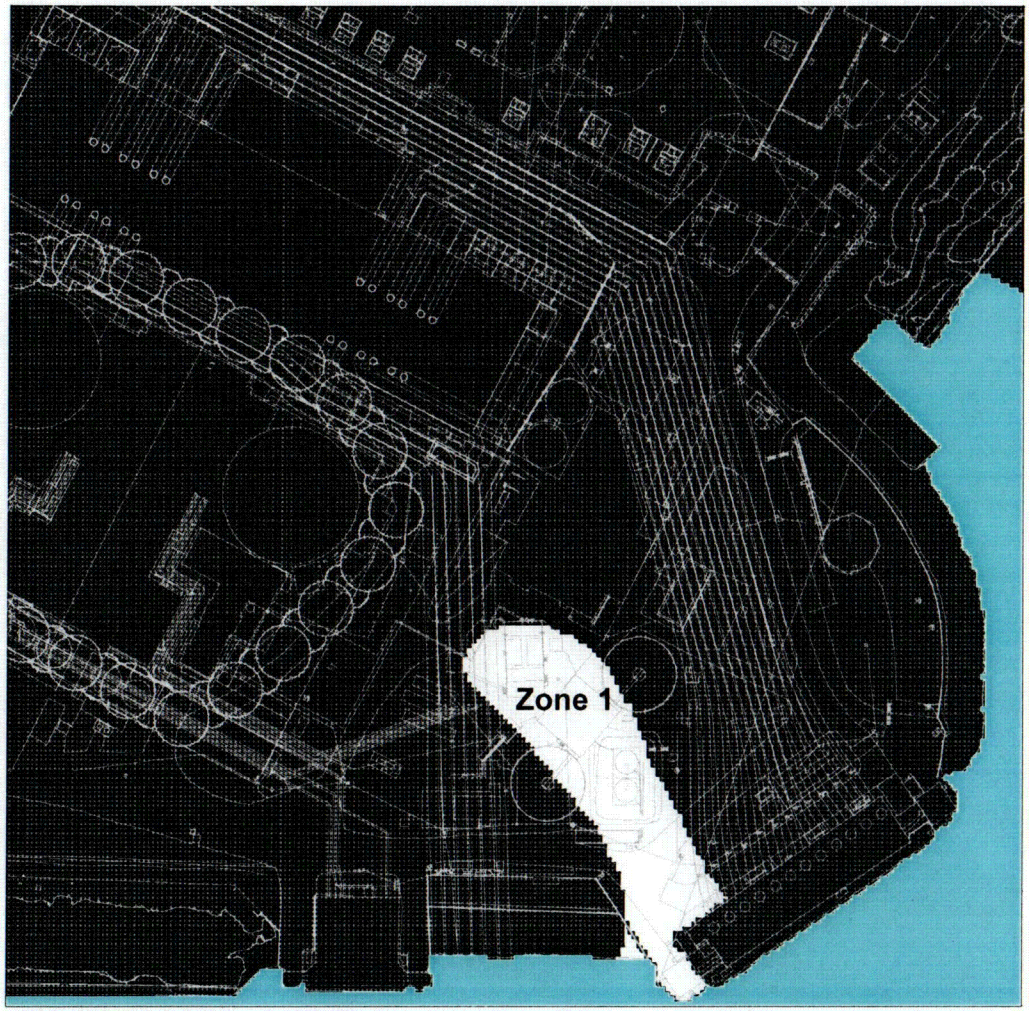
Model Domain, Boundary Conditions, and Hydraulic Conductivity Zonation - Model Layer 9

PSEG NUCLEAR, LLC
Salem Generating Station

FIGURE

B-16

DWG DATE: 5/14/04	PRJCT NO.: NP000571.0004.00005	FILE NO.: Figure17.srf	CHECKED: STP	APPROVED: PM	DRAFTER: SW



Legend

- No Flow Cells
- Constant Head Cells
- Sheet Pile

Hydraulic Conductivity Zonation

	Kh/Kv (ft/day)
Zone 1	6.5/0.65
Zone 2	2.5/0.25
Zone 3	0.3974/0.03974
Zone 4	0.125/0.0125

0ft 200ft 400ft

Scale: 1"=200'

ARCADIS

Model Domain, Boundary Conditions, and Hydraulic Conductivity Zonation - Model Layer 10

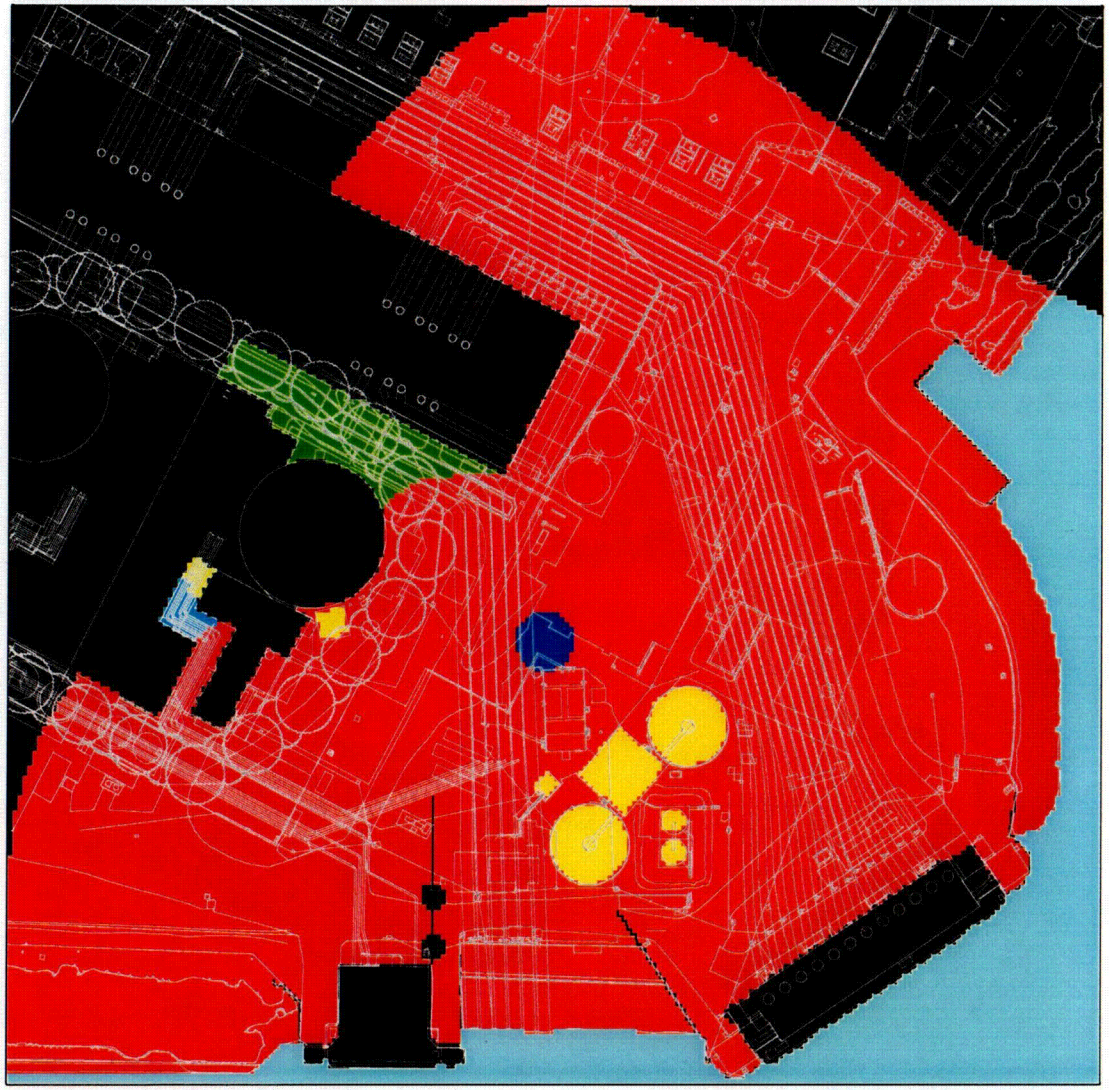
PSEG NUCLEAR, LLC
Salem Generating Station

FIGURE

B-17

C20

DWG DATE:	5/14/04	PRJCT NO.:	NP000571.0004.00005	FILE NO.:	Figure18.srf	CHECKED:	STP	APPROVED:	PM	DRAFTER:	SW



Legend

- No Flow Cells
- Constant Head Cells
- Sheet Pile

Precipation Recharge Zonation

	in/yr
Zone 1	8.5
Zone 2	0.33
Zone 3	0.82
Zone 4	20.0
Zone 5	0

0ft 200ft 400ft

ARCADIS

Model Domain, Boudary Conditions, Recharge Zonation

PSEG NUCLEAR, LLC
Salem Generating Station

FIGURE

B-18

C21

DWG DATE:	5/14/04	PRJCT NO.: NP000571.0004.00005	FILE NO.:	Figure19.srf	CHECKED:	STP	APPROVED:	PM	DRAFTER:	SW

Legend

- No Flow Cells
- Constant Head Cells
- Sheet Pile
- 91 — Water Table Contour (Plant Datum)
- 0.10 Residual
- Groundwater Flow Direction

0ft 200ft 400ft

ARCADIS

Simulated Water Levels and Residuals - Model Layer 1

PSEG NUCLEAR, LLC
Salem Generating Station

FIGURE

B-19

C22

DWG DATE:	5/14/04	PRJCT NO.:	NP000571.0004.00005	FILE NO.:	Figure20.srf	CHECKED:	STP	APPROVED:	PM	DRAFTER:	SW

Legend

- No Flow Cells
- Constant Head Cells
- Sheet Pile
- 91 — Water Table Contour (Plant Datum)
- 0.10 — Residual
- Groundwater Flow Direction

0ft 200ft 400ft

ARCADIS

Simulated Water Levels and Residuals - Model Layer 2

PSEG NUCLEAR, LLC
Salem Generating Station

FIGURE

B-20

C23