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SEQUOYAH NUCLEAR PLANT

INVESTIGATION OF TRITIUM RELEASES TO GROUNDWATER

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Knoxville, Tennessee
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mm/3

TABLE OF CONTENTS

LIST OF FIGURES

Acronyms and Abbreviations

CBI	Chicago Bridge & Iron
CCW	Condenser Circulating Water
CDWE	Condensate Demineralizor Waste Evaporator
CVCS	Chemical and Volume Control System
EPA	Environmental Protection Agency
ERCW	Essential Raw Cooling Water
GIS	Geographic Information System
GWSI	Ground-Water Site Inventory
LLRWSF	Low Level Radwaste Storage Facility
MDC	Minimum Detection Concentration
MFTDS	Modularized Transfer Demineralization System
MWe	Megawatt Electric
MWt	Megawatt Thermal
NEI	Nuclear Energy Institute
NRC	Nuclear Regulatory Commission
NRWT	Nonreclaimable Waste Tank
NT	Neutralization Tank
ODCM	Offsite Dose Calculation Manual
pCi/L	Picocuries per liter
PER	Problem Evaluation Report
Rad DI	Radwaste Demineralizer System
RCA	Radiation Control Area
REMP	Radiological Environmental Monitoring Program
RWST	Refueling Water Storage Tank
SQN	Sequoyah Nuclear Plant
TRM	Tennessee River Mile
TVA	Tennessee Valley Authority
USGS	United State Geological Survey
WARL	Western Area Radiological Laboratory
WBN	Watts Bar Nuclear Plant

1.0 INTRODUCTION

1.1 Purpose and Objectives

The Tennessee Valley Authority (TVA) is committed to controlling licensed material, minimizing potential unplanned, unmonitored releases to the environment from plant operations, and minimizing long-term costs associated with potential groundwater and subsurface contamination. Although current public health standards and limits are deemed appropriate, they may not satisfy public trust issues when unplanned releases occur. In conjunction with the Nuclear Energy Institute (NEI), TVA has approved a voluntary policy to enhance detection, management and communication about inadvertent radiological releases in groundwater. The investigation described herein represents an initial step in policy implementation.

In August 2006, a team consisting of GeoSyntec Consultants, Sequoyah Nuclear Plant (SQN) staff, and corporate TVA personnel was established to locate potential source(s) of site tritium releases and to identify potential migration route(s) to groundwater. This report provides findings of the site subsurface investigation with recommendations for the path forward. The primary objectives of the investigation were to:

- Identify potential radionuclide contaminant sources that account for observed measurements,
- Assess the nature and extent of subsurface tritium contamination, and
- Characterize groundwater movement to evaluate potential contaminant migration routes.

Tasks associated with this investigation included:

- Comprehensive review of historical radiological release information,
- Review of site drawings and plant construction photographs,
- Installation and sampling of soil borings and groundwater monitoring wells,
- Enhanced sampling of existing monitoring wells,
- Visual inspections and manual sampling of yard drains, sumps, manholes, and internal seeps,
- Manual and continuous water level monitoring, and
- Internal components investigations of both units using visual and boroscope methods.

1.2 Plant Description

SQN is a two-unit nuclear power plant located approximately 7.5 miles northeast of Chattanooga at the Sequoyah site in Hamilton County, Tennessee. The plant has been designed, built, and is operated by TVA. Each of the two identical units (Units 1 and 2; Figure 1.1) employs a Pressurized Water Reactor Nuclear Steam Supply System with four coolant loops furnished by Westinghouse Electric Corporation. These units are similar to those of TVA's Watts Bar Nuclear Plant.

Each of the two reactor cores is rated at 3,455 MWt and, at this core power, each unit will operate at 3,467 MWt. The additional 12 MWt is due to the contribution of heat of the Primary Coolant System from nonreactor sources, primarily reactor coolant pump heat. The total generator output is 1,199 MWe. for the rated core power. The containment for each of the reactors consists of a freestanding steel vessel with an ice condenser and separate reinforced Concrete Shield Building. The ice condenser was designed by the Westinghouse Electric Corporation. The freestanding containment vessel was designed by Chicago Bridge & Iron (CBI). Unit 1 began commercial operation on July 1, 1981. Unit 2 began commercial operation on June 1, 1982.

1.3 Historical Tritium Monitoring

As part of the SQN onsite Radiological Environmental Monitoring Program (REMP), quarterly groundwater monitoring for tritium began in 1971 at four bedrock monitoring wells (W1, W2, W4, and W5) located along the perimeter of the site (Figure 1.2). Onsite REMP groundwater monitoring was reduced to a single well (W5) in 1980. Tritium was initially observed in SQN groundwater at well W5 from 1989 sampling at a background concentration of 379 picocuries per liter (pCi/L). No other detection of tritium was observed at well W5 until 1998. From 1998 through 2001, tritium was consistently observed at concentrations ranging from 401 to 2,120 pCi/L at well W5. No further tritium detection has been observed at well W5 since 2001.

Evaluation of REMP data indicates no evidence of tritium or other radionuclides exceeding detection levels in offsite surface water or groundwater samples since 1992. Pre-1992 tritium concentrations in offsite surface water and groundwater samples reflect ambient concentrations resulting most probably from cosmogenic sources and nuclear weapons testing from the 1940s through the 1970s.

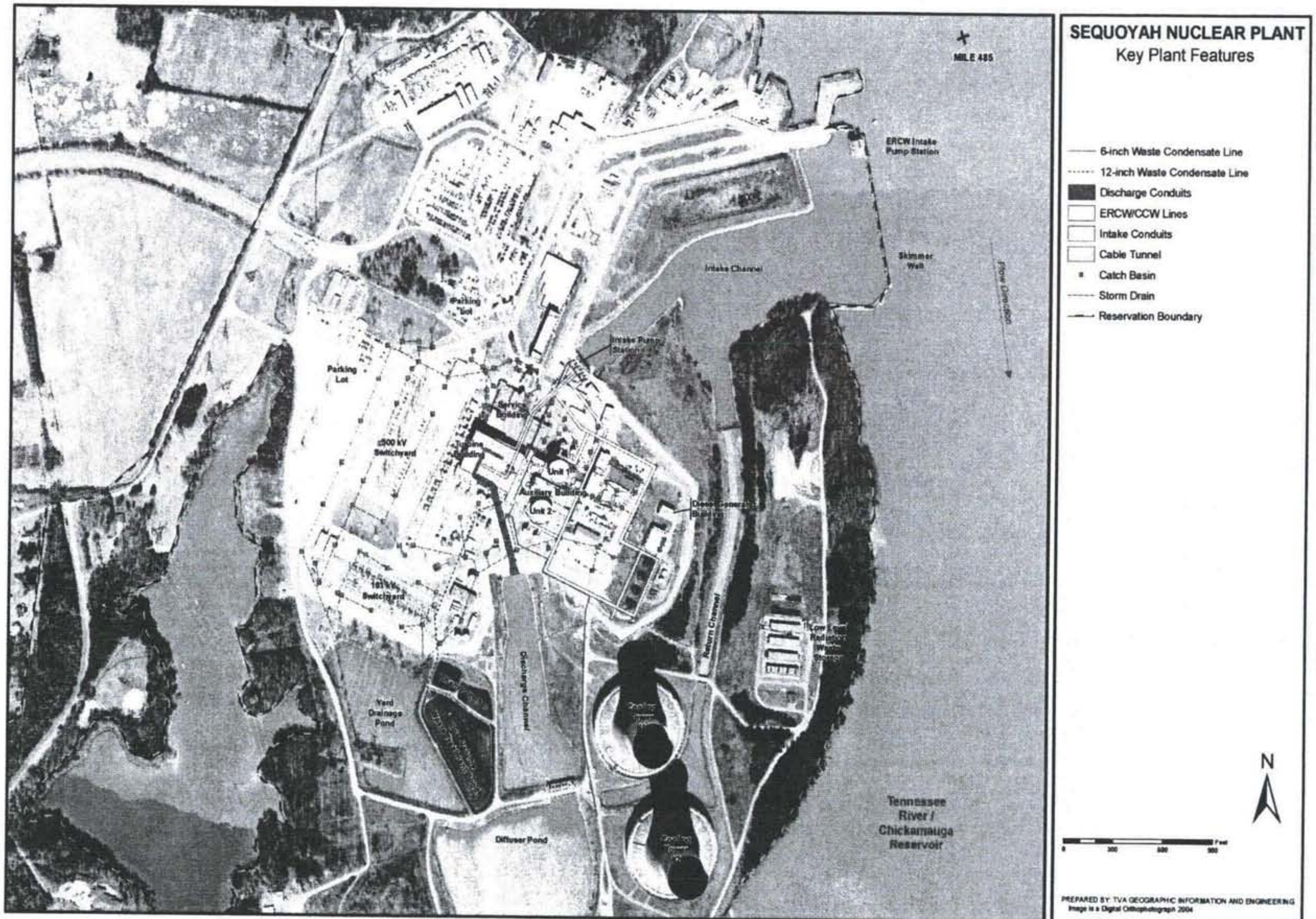


Figure 1.1 Site Map Showing Key Plant Features

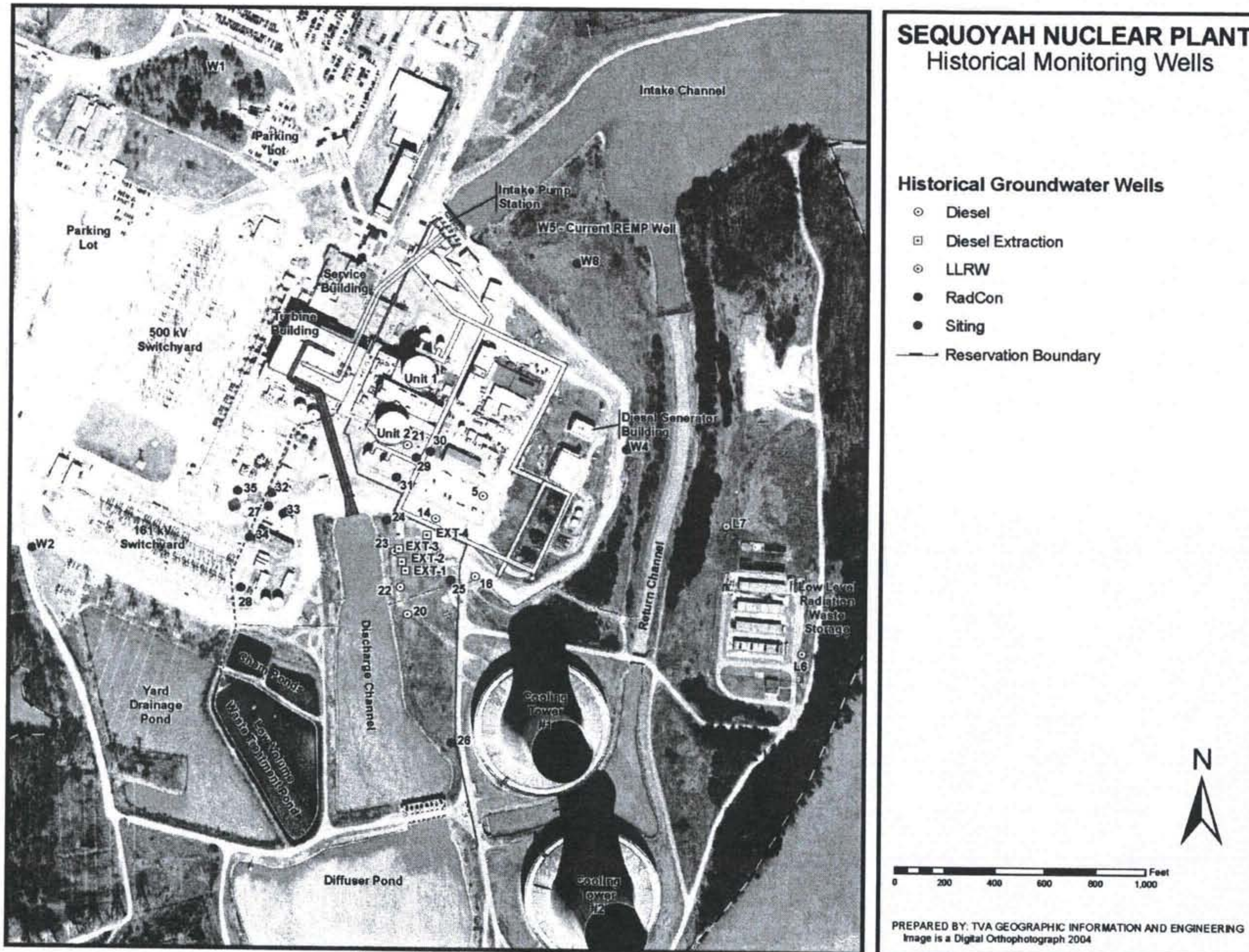


Figure 1.2 Site Map Showing Historical Monitoring Wells

In February 2002, TVA expanded the REMP groundwater monitoring at SQN by installing five additional soil monitoring wells (wells 24 – 28) along 6- and 12-inch diameter condensate pipelines. These lines convey condensate and radwaste effluent from the Turbine and Auxiliary Buildings, respectively (Figure 1.1). The 6- and 12-inch lines discharge into the 72-inch cooling tower blow-down line and Low-Volume Waste Treatment Pond, respectively. Initial samples collected from these wells indicated no evidence of tritium (<220 pCi/L).

Monthly groundwater sampling for tritium was prescribed for well 27 beginning in August 2003. Tritium was consistently observed slightly above the minimum detection concentration (MDC) of 220 pCi/L at this well beginning in September 2003. The consistency of observations prompted a sampling event in January and February 2004 that included other site wells (W14 and W21) in conjunction with manual sampling of vicinity sumps, moats, storm drain catch basins, and ponds. A relatively high tritium concentration of 9,080 pCi/L was observed at well 21. A subsequent set of seven monitoring wells (wells 29 – 35) were installed in April 2004, with routine sampling of selected wells beginning in May 2004. To date, tritium concentrations in these wells have ranged from MDC to 19,750 pCi/L. These concentrations have not exceeded the Environmental Protection Agency (EPA) Drinking Water Standard of 20,000 pCi/l for tritium (40 CFR 141.25). The Nuclear Regulatory Commission (NRC) Site Resident at SQN has been notified and is being kept informed as investigations continue.

2.0 BACKGROUND

2.1 Radiological Environmental Monitoring Program (REMP)

The preoperational environmental monitoring program has established a baseline of data on the distribution of natural and manmade radioactivity in the environment near the plant site. The preoperational environmental monitoring program was initiated in the spring of 1971. The operational monitoring program initiated in the spring of 1980 reflects the current monitoring philosophy and regulatory guidelines.

REMP reports have been prepared by TVA's Western Area Radiological Laboratory (WARL) and SQN personnel since inception of the program in 1971. The SQN REMP has been modified over time to adjust for sampling locations, sampling methods, analytes, reporting frequency, and changes in laboratory methods/instruments and MDCs.

Currently, REMP reports catalog onsite direct radiation sampling, atmospheric radiation monitoring at eight sites located 10 to 20 miles from the plant, terrestrial radiation monitoring at area farms within six miles of the plant, and liquid pathway radiation monitoring along the Tennessee River and from area groundwater wells.

TVA participates in an Interlaboratory Comparison Program. This program provides periodic cross-check samples of the type and radionuclide composition normally analyzed in an environmental monitoring program. Results obtained in the monitoring and the cross-check programs are reported annually to the NRC.

Groundwater and surface water sampling have been a part of the program since it was instituted in 1971, and remain part of the current liquid pathway monitoring program. Onsite and offsite monitoring locations for groundwater and surface water are shown in Figures 2.1 and 2.2, respectively.

2.1.1 REMP Groundwater

The monitoring well network at SQN (Figure 1.2) included six regional monitoring wells (wells W1, W2, W4, W5, and W8) that were installed before 1977. Quarterly groundwater monitoring for tritium began in 1977 at four bedrock monitoring wells (W1, W2, W4, and W5) located along the perimeter of the site (Figure 2.1). Onsite REMP groundwater monitoring was reduced to a single well (W5) in 1981. Offsite groundwater sampling also began in 1977 at seven area farms; but, since 1986 samples have been collected at just one location (Farm HW well; see Figure 2.2).

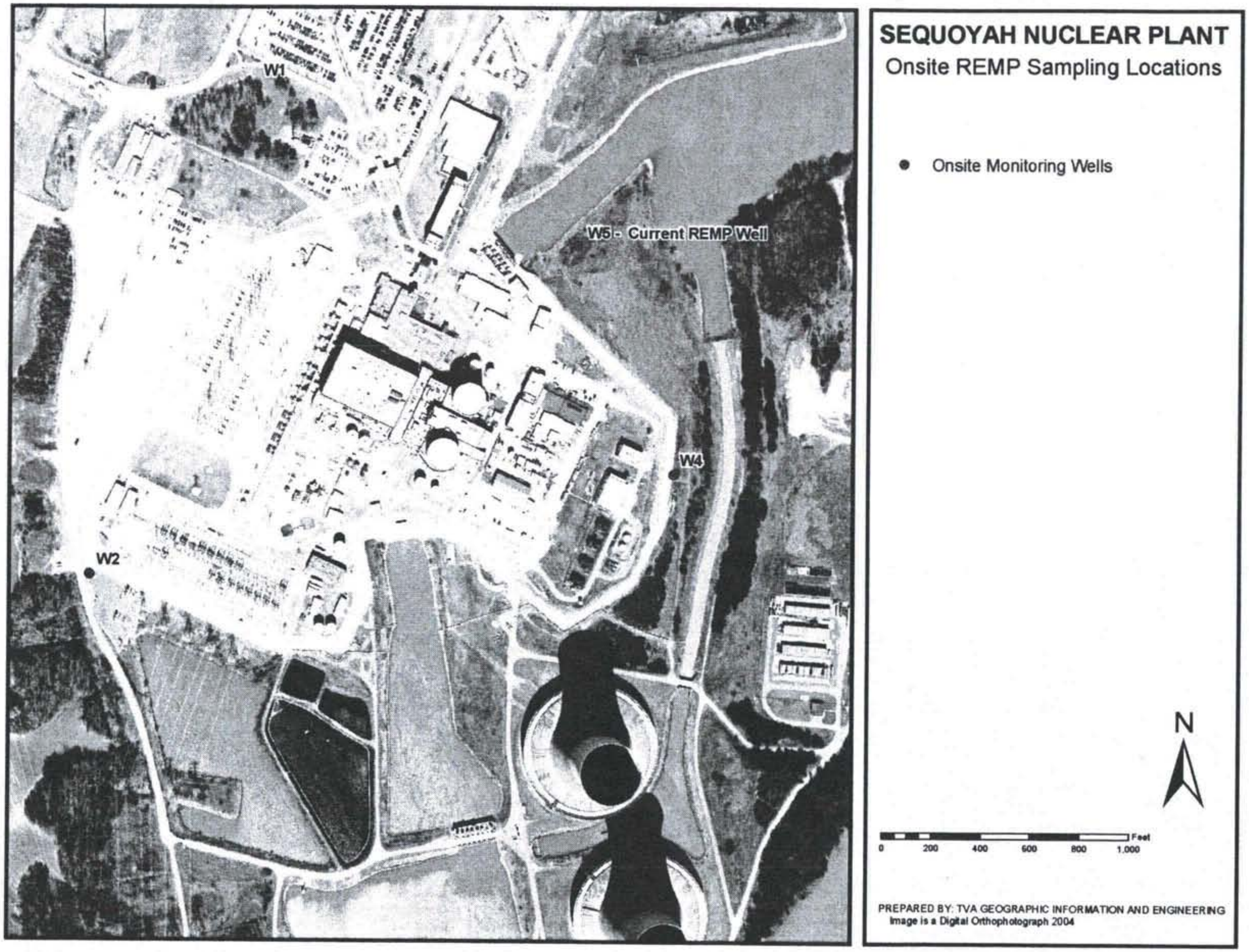


Figure 2.1 Onsite REMP Sampling Locations for Groundwater and Surface Water

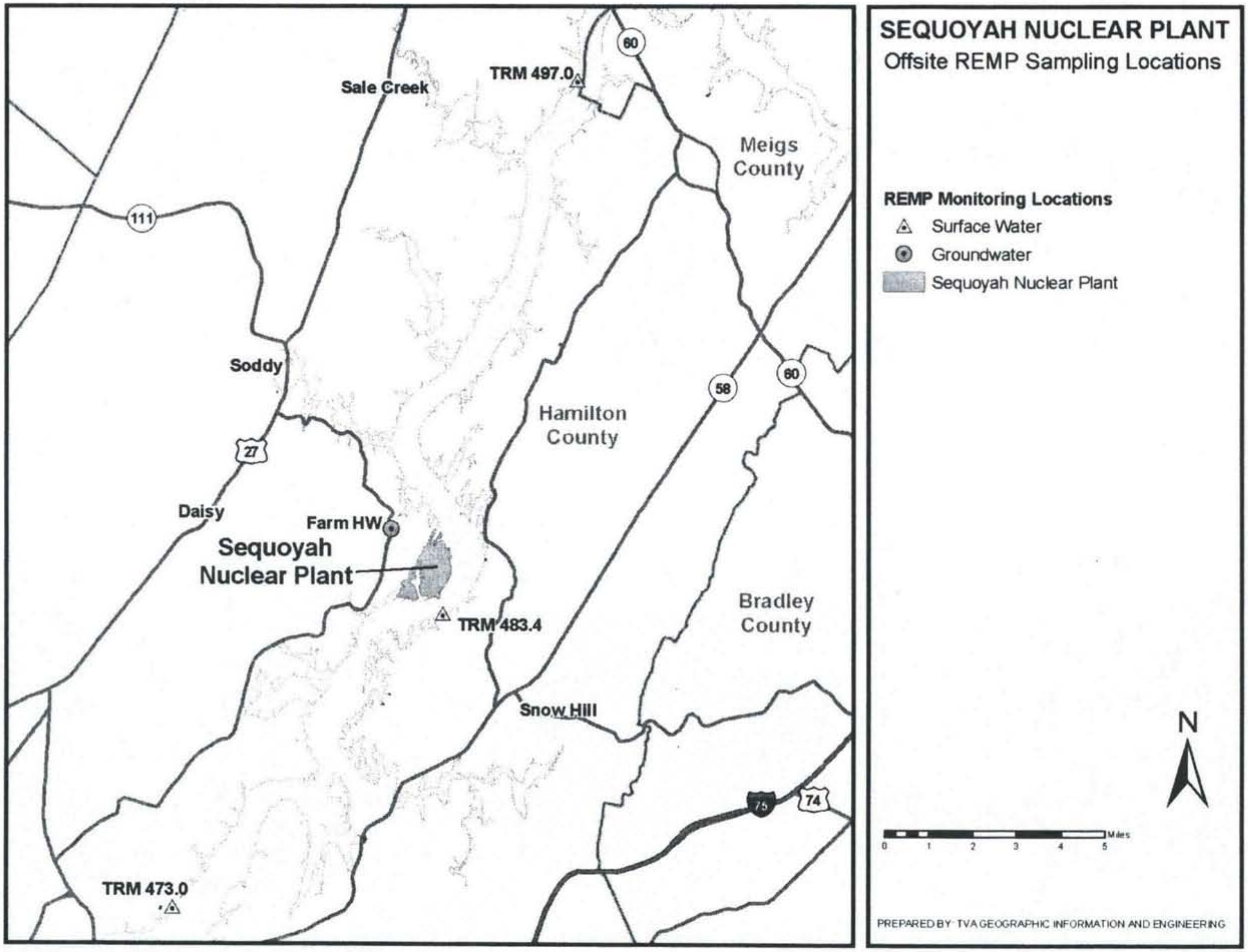


Figure 2.2 Offsite REMP Sampling Locations for Groundwater and Surface Water

In the earlier years, groundwater was collected by grab sampling. Sometime in the late 1970s or early 1980s, well W5 was equipped with an automatic sampler. The automatic sampler transmits a daily sample aliquot to a composite container for monthly retrieval. Manual samples are collected quarterly from the offsite Farm HW well.

Quarterly samples are analyzed by gamma spectroscopy using a one pass method with an intrinsic germanium detector (Vortec and Canberra instruments). Samples are first distilled by centrifuging 50 ml of liquid, distilling that volume (if it is turbid), and then extracting 15ml to be analyzed. The composite sample is analyzed by gamma spectroscopy for gross beta activity (monthly) and tritium analysis is conducted on a quarterly basis. Tritium analysis is completed by liquid scintillation methods using a Packard scintillation unit. A total of five scintillation counts are performed for each test. Results are reported as the mean of the three highest counts.

Results of REMP groundwater monitoring are shown in Figure 2.3. From the period 1977 – 1998, both onsite and offsite groundwater monitoring indicates tritium concentrations that are <MDC or are within the range of expected background concentrations. Tritium was initially observed in SQN groundwater at onsite well W5 from 1989 sampling at a background concentration of 379 pCi/L. No other detection of tritium was observed at well W5 until 1998. However, from 1998 through 2001, tritium was consistently observed at concentrations ranging from 401 to 2,120 pCi/L at well W5. No further tritium detection has been observed at well W5 since 2001. During the period 1998 – 2001, tritium concentrations at the offsite Farm HW well and at all surface water monitoring locations were <MDC (Figure 2.3). Hence, tritium observations at well W5 during the 1998 – 2001 time interval exceed background concentrations and suggest an onsite source of contamination.

2.1.2 REMP Surface Water

Surface water sampling locations have remained constant throughout the REMP program, including one upstream location and two downstream locations (Figure 2.2). The upstream sampling location is the City of Dayton drinking water supply intake station at Tennessee River Mile (TRM) 497.0. The downstream samples are collected at Eastside Utility District water intake (TRM 473.0) and at a temperature station 0.3 mile downstream from the SQN discharge (TRM 483.4).

Samples are collected by automatic ISCO samplers at each of the three locations. The instruments are programmed to accumulate discreet samples every two hours and composite samples are collected monthly. The composite sample is analyzed for gross beta activity (monthly) and tritium (quarterly) using the methods described in Section 2.1.1.

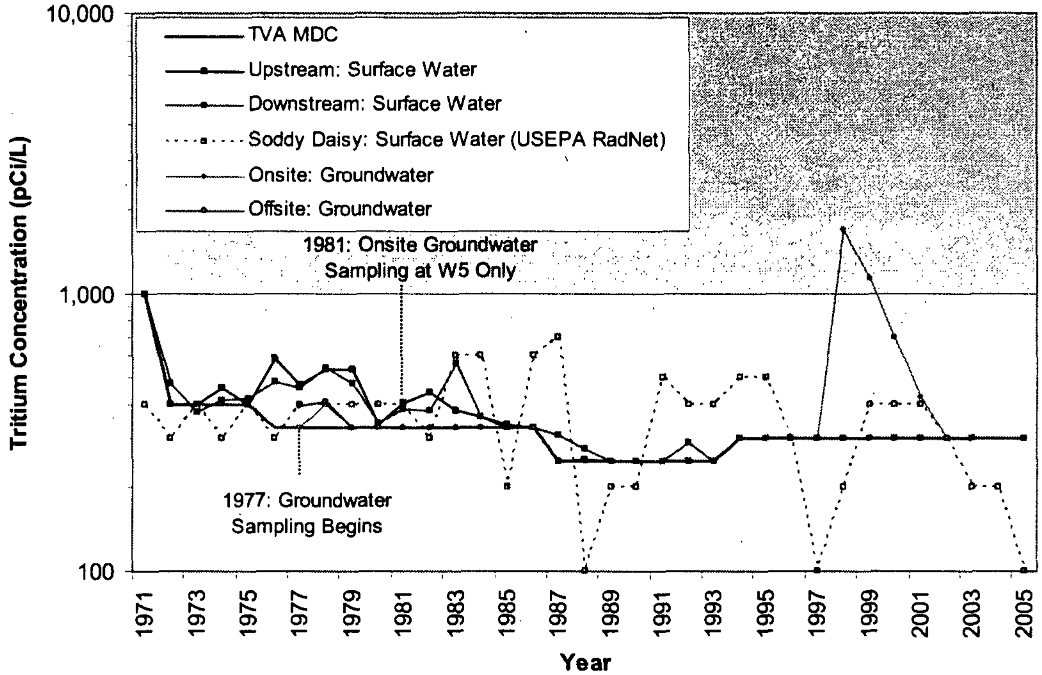


Figure 2.3 Time-Series Tritium Concentrations from REMP Groundwater and Surface Water Monitoring

Results of REMP surface water monitoring are shown in Figure 2.3. For comparison, USEPA RadNet surface water data (USEPA, 2007) for Soddy Daisy, Tennessee are depicted in the figure. The SQN REMP data indicate no evidence of tritium or other radionuclides exceeding detection levels in offsite surface water or groundwater samples since 1992. Pre-1992 tritium concentrations in surface water samples reflect ambient concentrations resulting most probably from cosmogenic sources and nuclear weapons testing from the 1940s through the 1970s.

2.2 Radwaste System

2.2.1 Liquid Radwaste System

Liquid, gaseous, and solid radwaste disposal facilities at SQN are designed so that discharges of effluents are in accordance with 10 CFR Parts 20 and 50. The Liquid Waste Processing System is designed to receive, segregate, process, recycle for further processing, and discharge liquid wastes. Liquids entering the Liquid Waste Processing System are collected in sumps and tanks until determination of subsequent treatment can be made. They are sampled and analyzed to quantify radioactivity, with an isotopic accounting if necessary. Processed radioactive wastes not suitable for reuse and the liquid waste suitable for reuse, whose volume is not needed for plant operations or not desired for reuse, are discharged from the plant or packaged for offsite disposal. Design and operation of the Radwaste System is characteristically directed toward minimizing releases to unrestricted areas. Under normal plant operation, the activity from radionuclides leaving the discharge canal is a small fraction of the limits in 10 CFR Parts 20 and 50.

2.2.1.1 System Descriptions

The Liquid Waste Processing System was initially designed to collect and process potentially radioactive wastes for recycle to the Reactor Coolant System or for release to the environment. The liquid waste processing system was, by original design, arranged to recycle as much reactor-grade water entering the system as practical. This was implemented by the segregation of equipment drains and waste streams, which prevents the intermixing of liquid wastes. The layout of the liquid waste processing system, therefore, consists of two main subsystems designed for collecting and processing reactor-grade (tritiated) and non-reactor-grade (non-tritiated) water, respectively. All liquids are now routinely processed as necessary for release to the environment instead of recycling, and are no longer maintained segregated based on tritium content during processing. This includes reprocessing the contents of tanks which accumulate waste water for discharge which may be unsuitable for direct release. Provisions are made to sample and analyze fluids before they are discharged. Based on the laboratory analysis, these wastes are either released under controlled conditions via the cooling water system or retained for further processing. A permanent record of liquid releases is provided by analyses of known volumes of waste. Actual radionuclide inventories of plant effluents are submitted to the NRC as a requirement of 10 CFR 50 by Nuclear Chemistry Offsite Dose Calculation Manual (ODCM).

In addition, a system is provided for handling laboratory samples which may be tritiated and may contain chemicals. Capability for handling and storage of spent demineralizer resins is also provided.

The plant system is controlled from a central panel in the Auxiliary Building and a panel in the main control room. All system equipment is located in or near the Auxiliary Building, except for the reactor coolant drain tank and drain tank pumps and the various Reactor Building floor and equipment drain sumps and pumps which are located in the Containment Building.

The Radwaste Demineralizer System (Rad DI) is located and operated in the Auxiliary Building railroad access bay when the vendor's service is requested.

At least two valves must be manually opened to permit discharge of liquid to the environment. One of these valves is normally locked closed. A control valve trips closed on a high effluent radioactivity level signal. Controls are provided to prevent discharge without dilutions.

2.2.1.2 Shared Components

Parts of the Liquid Waste Processing System are shared by the two units. The Liquid Waste Processing System consists of one reactor coolant drain tank with two pumps, an Auxiliary Reactor Building floor and equipment drain sump with two pumps, a keyway sump with one pump, and a Reactor Building floor and equipment drain sump with two pumps inside the Containment Building of each unit. It also includes the following shared equipment located inside the Auxiliary Building: one sump tank and two pumps; one tritiated drain collector tank with two pumps and one filter; one floor drain collector tank with two pumps and one strainer; a monitor tank and two pumps; a chemical drain tank and pump; two hot shower tanks and pump; a spent resin storage tank; a cask decontamination tank with two pumps and two filters; the Auxiliary Building floor and equipment drain sump and two pumps; a passive sump; a Radwaste Demineralizer System; and the associated piping, valves, and instrumentation.

The following shared components are located in the Condensate Demineralizer Building for receiving, processing, and transferring wastes from the regeneration of condensate demineralizers: high crud, low conductivity tanks, pumps, and filters; a neutralizer tank and pumps; and a non-reclaimable waste tank and pumps.

2.2.1.3 Separation of Tritiated and Nontritiated Liquids

Waste liquids that are high in tritium content are routed to the tritiated drain collector tank; while liquids low in tritium content are routed to the floor drain collector tank. All tritiated and nontritiated liquid waste are processed for discharge to the environment.

2.2.1.4 Tritiated Water Processing

Tritiated reactor grade water is processed for discharge to the environment or for recycle to the primary water storage tank. The water enters the liquid waste disposal system from equipment leaks and drains, valve leakage, pump seal leakage, tank overflows, and other tritiated and aerated water sources including draining of the Chemical and Volume Control System (CVCS) holdup tanks, as desired.

The equipment provided in this channel consists of a tritiated drain collector tank, pumps, and filter and Radwaste Demineralizer System. The primary function of the tritiated drain collector tank is to provide sufficient surge capacity for the radwaste processing equipment.

The liquid collected in the tritiated drain collector tank contains boric acid, and fission product activity. The liquid can be processed as necessary to remove fission products so that the water may be reused in the Reactor Coolant System or discharged to the environment.

2.2.1.5 Nontritiated Water Processing

Nontritiated water is sampled and processed as necessary for discharge to the river. The sources include floor drains, equipment drains containing nontritiated water, certain sample room and radiochemical laboratory drains, hot shower drains and other nontritiated sources. The equipment provided in this channel consists of a floor drain collector tank, pumps, and strainer, Radwaste Demineralizer System, hot shower tanks and pump, cask decontamination collector tank and pumps, and monitor tank and pumps.

Liquids entering the floor drain collector tank are from small volume, low activity sources. If the activity is below permissible discharge levels following analysis to confirm acceptably low level, then the tank contents may be discharged without further treatment other than filtration. Otherwise, the tank contents are processed through the Radwaste Demineralizer System.

The hot shower drain tanks normally need no treatment for removal of radioactivity. The inventory of these tanks may be discharged directly to the cooling tower blowdown via the hot shower tank strainer or to other tanks in the liquid waste system.

The liquid waste system is also designed to process blowdown liquid from the steam generators of a unit having primary-to-secondary leak coincident with significant fuel rod clad defects. The blowdown from the steam generators is passed through the condensate demineralizer or directly to the cooling tower blowdown line.

2.2.1.6 Releases of Liquid Radwaste

The Tennessee River/Chickamauga Lake is the sole surface water pathway between SQN and surface water users along the river. Liquid effluent from SQN flows into the river from a diffuser pond through a system of diffuser pipes located at TRM 483.65. The contents of the diffuser pond enter the diffuser pipes and mix with the river flow upon discharge. The diffusers are designed to provide rapid mixing of the discharged effluent with the river flow. The flow through the diffusers is driven by the elevation head difference between the diffuser pond and the river. Flow into the diffuser pond occurs via the blowdown line, Essential Raw Cooling Water (ERCW) System, and Condenser Circulating Water (CCW) System. Two parallel pipelines comprise the diffuser system which is designed to provide mixing across nearly the entire width of the main channel.

Release of radioactive liquid from the Liquid Waste Processing System can be from the cask decontamination collector tank, CVCS monitor tank, hot shower tanks, or chemical drain tank to the cooling towers blowdown line via the 6-inch diameter Waste Condensate Line (Figure 1.1). The cooling tower blowdown line empties into the diffuser pond which discharges into the river through the diffuser pipes. Liquid wastes from the condensate Demineralizer system are released from the high crud low conductivity tanks, the non-reclaimable waste tank, and the neutralization tank.

The CCW system operates in three modes: open, closed, and helper. In the open mode, the cooling towers are not used. Cooling water is pumped from the intake and through the condenser, and is discharged into the diffuser pond. Dilution water for the radioactive liquid is provided by ERCW, which is in continuous operation and discharges to the cooling tower cold water canal. A weir at Gate Structure 1 ensures that under most river level conditions, the ERCW flow is diverted through the cooling tower blowdown line. The radioactive liquid is mixed with ERCW in the cooling tower blowdown line and flows into the diffuser pond.

In the closed mode, CCW is recirculated between the cooling towers and the condenser. In this mode of operation, the cooling towers blowdown flows at a minimum of 150,000 gpm into the diffuser pond in order to maintain the solids in the cooling water at an acceptable level.

In the helper mode, the CCW from the condenser goes through the cooling towers and is released to the diffuser pond through Gate Structure 1 and the cooling tower blowdown line.

Release of the radioactive liquids from the liquid waste system is made only after laboratory analysis of the tank contents. Once the fluids are sampled, they are pumped to the discharge pipe through a remotely operated control valve, interlocked with a radiation monitor and with instrumentation to ensure adequate dilution flow in the cooling tower blowdown line.

Minimum dilution flow can also be determined via ERCW flow instrumentation, or by periodic flow rate estimation. A similar arrangement is provided for wastes discharged from the condensate demineralizer waste system. The flow control valve is interlocked with a radiation monitor. Release of wastes will be automatically stopped by a high radiation signal.

The steam generator blowdown system may discharge radioactive liquid. Liquid waste from this system is not collected in tanks for treatment, but is continuously monitored for radioactivity and may discharge to the cooling tower blowdown, or recirculate to the condensate system upstream of the condensate demineralizers. The flow control valve in the discharge line is interlocked with a radiation monitor and with instrumentation to ensure adequate dilution flow on the cooling tower blowdown. Minimum dilution flow can also be determined via ERCW flow instrumentation, or by periodic flow rate estimation.

The Turbine Building sump collects liquid entering the Turbine Building floor drain system or from clean water sources in the Auxiliary Building that are transferred to the Turbine Building sump. When the sump is nearly full (maximum capacity 30,000 gallons), the liquid is automatically discharged (level initiated) to the Low-Volume Waste Treatment Pond or the Yard Drainage Pond via the 12-inch diameter Waste Condensate Line (Figure 1.1). The Yard Drainage Pond drains by gravity to the Diffuser Pond which ultimately discharges to the river via the diffusers.

Means are provided for radiological monitoring during normal operations, including anticipated operational occurrences, and during accident condition various process streams and gaseous and liquid effluent discharge paths. Some of the monitors initiate automatic control actions. Continuous radiological monitoring instruments for liquid processes and effluents include the following locations.

1. Station Sump Discharge Monitor (Turbine Building)
2. Waste Disposal System Discharge Monitor (Auxiliary Building)
3. ERCW Discharge Monitor (Headers A & B)
4. Condensate Liquid Demineralizer Monitor (Demineralizer Building)
5. Steam Generator Blowdown Liquid Discharge Monitor (Turbine Building)
6. Component Cooling System Monitor (Auxiliary Building)

The release locations are also subject to periodic sampling and include all liquid releases which could exceed the limits given in Appendix I, 10 CFR 50 and 10 CFR 20. The sampling and analysis requirements for these release points are defined in the SQN ODCM controls. The plant discharge meets Regulatory Guide 1.21 Revision 1, 10 CFR 20, and 10 CFR 50 guidelines.

The offsite dose calculations for drinking water are based on the assumption that the liquid effluent will be mixed with 60 percent of the river flow between the point of discharge and Chickamauga Dam. Although further mixing will occur, 60 percent dilution is assumed to be maintained for approximately 14 miles until Chickamauga Dam (TRM 471.0) is reached where 100 percent dilution is assumed to occur.

2.2.2 Waste Condensate Lines

Figure 1.1 shows the locations of the 6- and 12-inch waste condensate lines at the site. The 12-inch waste condensate line receives water from the Turbine Building sump. Turbine Building drains are collected in the Turbine Building sump or discharged directly to various ponds or CCW discharge. Non-radioactive raw cooling water booster pump skid drains, SGB sample panel drains, and auxiliary feedwater pump leakoff drains are also collected in the Turbine Building sump. A temporary-use manifold allows RADCON-approval drainage (e.g., Cycle Outage Ice Melt) to be discharged to the Turbine Building sump. The header penetrates the Auxiliary/Turbine Building wall connecting to an existing drain (old titration room drain) and travels by gravity to the sump.

High conductivity chemical regenerate and rinse wastes that are produced during condensate demineralizer regeneration are routed to the neutralization tank (NT) or, alternately, to the nonreclaimable waste tank (NRWT) where they are collected and neutralized. If the contents of either tank (NT or NRWT) are not radioactive or if the radioactivity level is less than the discharge limit, it is transferred to the Turbine Building sump and subsequently discharged through the low volume waste treatment pond, or alternately it is discharged to the cooling tower blowdown via the 6-inch waste condensate line. If the contents of either the NT or NRWT are radioactive, they may be discharged to the cooling tower blowdown if the radioactivity level is within specification; otherwise, they are processed by the radwaste system.

The Turbine Building sump level is controlled by a high-low level switch that energizes the sump pumps. The sump effluents can be routed to the Yard Drainage Pond or the Low Volume Waste Treatment Pond.

The 6-inch waste condensate line receives routine (almost daily) radioactive effluent discharges from the Liquid Waste Processing System described in preceding sections. Potential leakage of this line was identified as a potential tritium source based on comparable tritium investigations completed at Watts Bar Nuclear Plant (WBN; ARCADIS, 2004), and similarity of SQN plant design to WBN.

The operating pressure of the 6-inch waste condensate line during a radwaste release varies from about 4 psig to negative pressure. Pressure testing of the 6-inch waste condensate line was performed under SQN work order no. 04-776838-004 on April 7, 2006. Service air was used to pressurize the line to 50 psig. After approximately 24 hours, the pressure was measured at 49 psig. After 70 hours the pressure was measured at 47 psig.

On July 10, 2006 a leakage test was performed by connecting a hose from the Demineralizer Water System to the waste condensate line and filling the pipeline. Following the initial fill, a rotometer was installed (range 0 – 120 cc/min). Experimentation with the rotometer indicated that the lower detection limit of flow was about 1 drop per second which corresponds to approximately 1.3E-05 gpm.

Flow was allowed to stabilize for three weeks. After this period and on two separate occasions, the water supply was isolated (valve closure) from the condensate line. After four days of isolation, the water supply valve was reopened. On each occasion, the ball in the rotometer was observed to have zero movement as the water supply valve was opened. Pressure gauge readings were obtained to ensure that the rotometer results were not invalidated by temperature changes in the condensate line. Results indicated that rotometer testing was valid. The test pressure was approximately 40 psig. Therefore, a leak was not observed at the detection limit of the rotometer and conclusions by SQN staff were that the line does not leak.

2.2.3 Gaseous Radwaste System

Controlled airborne releases from the plant ventilation system may result in measurable atmospheric deposition of plant-related radionuclides (including tritium) in the vicinity of the site. Some of this material may accumulate on plant roof surfaces and discharge into roof drains during precipitation events. Rain may also wash airborne releases onto facility soil and building surfaces.

The impact of this potential source of groundwater contamination may vary substantially with release periods and meteorological conditions. While this potential source is not likely to be a major contributor to groundwater contamination, operators of at least one nuclear power plant believe that measurable tritium concentrations in groundwater at their site are likely due to the deposition of tritium in airborne effluents (NRC, 2006). Recognition that atmospheric deposition may be a process actively contributing to observed wide-spread, low-level tritium concentrations in groundwater would allow explanation of the presence of these low-level concentrations when no other potential source can be identified.

The Gaseous Waste Processing System is designed to remove fission product gases from the reactor coolant and to permit operation with periodic discharges of small quantities of fission gases through the monitored plant vent. This is accomplished by internal recirculation of radioactive gases and holdup in the nine gas decay tanks to reduce the concentration of radioisotopes in the released gases. The offsite exposure to individuals from gaseous effluents released during normal operation of the plant is limited by Appendix I of 10 CFR 50 and by 40 CFR 190.

The Gaseous Waste Processing System consists of two waste-gas compressor packages, nine gas decay tanks, and the associated piping, valves and instrumentation. The equipment serves both units. Gaseous wastes can be received from the following: degassing of the reactor coolant and purging of the volume control tank prior to a cold shutdown, displacing of cover gases caused by liquid accumulation in the tanks connected to the vent header, purging of some equipment, sampling and gas analyzer operation, and boron recycle process operation (no longer in service).

Gaseous radioactive wastes are released to the atmosphere through vents located on the Shield Building, Auxiliary Building, Turbine Building, and Service Building.

2.3 Inadvertent Releases of Liquid Radwaste

Design and operation of the Radwaste System is characteristically directed toward minimizing releases to unrestricted areas. However, accidental releases of radioactive effluents and unusual occurrences to outdoor environs at SQN have been documented by TVA (2006) for the period from July 1981 (Unit 1 startup) to July 2006. A comprehensive review of these data is important for this investigation since these historical releases may serve as sources of tritium identified within the site groundwater system. Records of releases by TVA (2006) are based on report documentation for most of the occurrences and via interviews conducted with SQN Radiation Protection staff for earlier events.

Eight accidental releases of radioactive effluents and unusual occurrences to outdoor environs at SQN have been documented to date. Figure 2.4 identifies the approximate locations of these events and descriptions are provided in the following paragraphs.

1. *Condensate Demineralizor Waste Evaporator (CDWE) Building – mid-1980s*

   Based on personnel interviews, radioactivity leached through a concrete wall of the CDWE Building to an outside concrete slab and soil. It is presumed that this was an aqueous release. Contaminated soil was excavated and the building wall was painted with sealant. Quarterly surveys (RMD-FO-35) were subsequently performed by Radiation Protection.

2. *Unit 2 Additional Equipment Building (Upper Head Injection) – mid-1980s*

   Based on personnel interviews, a hose burst spraying water through a door to outside environs. An asphalt area was painted with sealant, and a vehicle and Porta-John toilet were decontaminated. Quarterly surveys (RMD-FO-35) were subsequently performed by Radiation Protection.

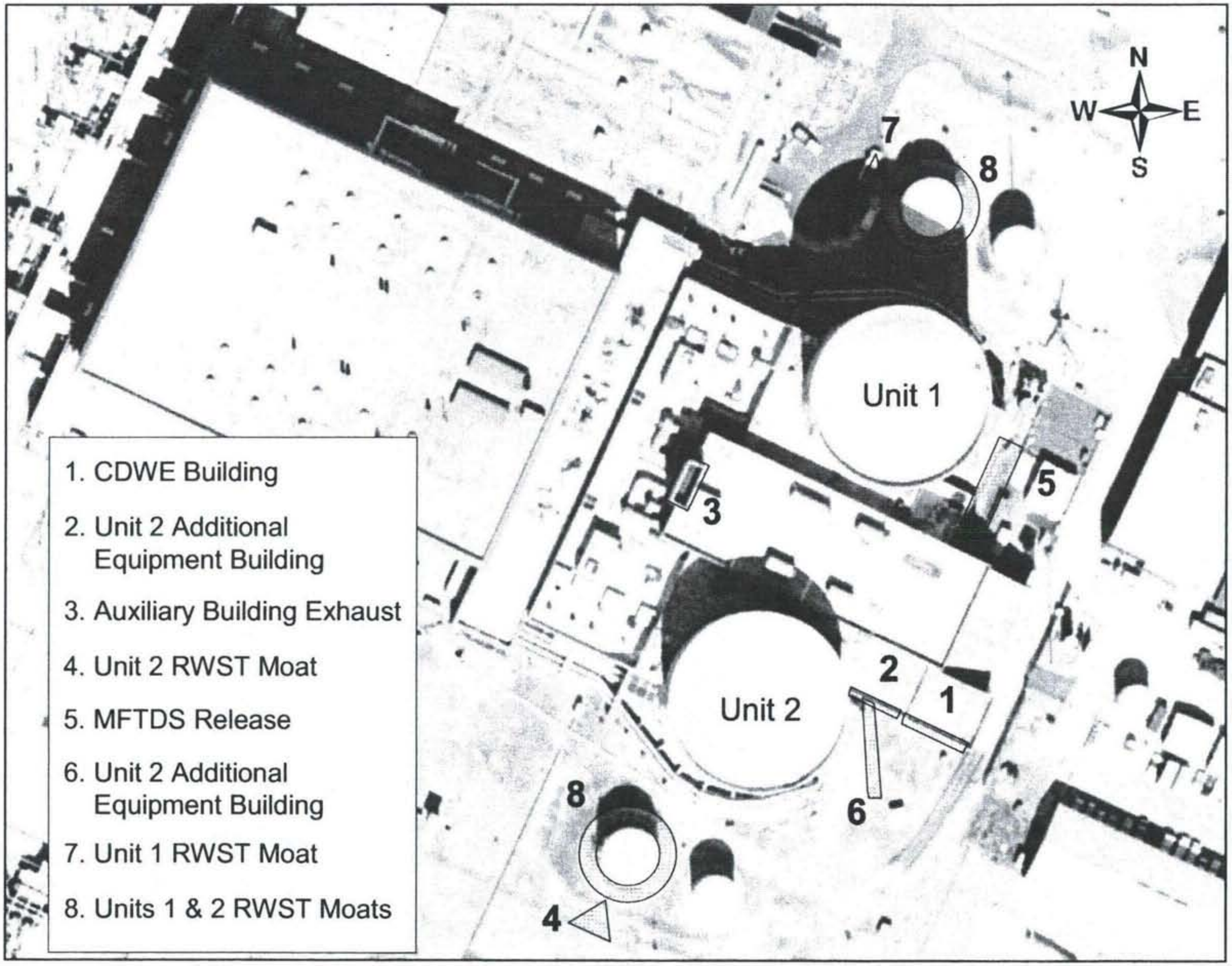


Figure 2.4 Site Map Showing Locations of Inadvertent Releases of Liquid RadWaste

3. Auxiliary Building Roof – early 1990s

Based on personnel interviews, radioactive contamination was discovered on the Auxiliary Building roof. Origin of contamination was determined to be unfiltered fuel handling ventilation trains associated with Auxiliary Building ventilation stack discharge. Remediation is cited as contamination being removed from the roof. Quarterly surveys (RMD-FO-35) were subsequently performed by Radiation Protection.

4. Unit 2 Refueling Water Storage Tank (RWST) Moat Drain – May 10, 1995

During performance of a routine environmental monitoring survey (RMD-FO-35), radioactivity was identified in soil at the moat drainage outlet of the Unit 2 RWST (Figure 2.5). The drain outlet is located on the south side of the moat and discharges to gravel covered soil. Follow-up sampling was performed and Co-58, Co-60, Cs-134, and Cs-137 were identified in soil in excess of the MDC of 5.0E-07 μCi/g. Documentation includes survey number D-95-0558 with attached sample gamma analysis results from WARL.

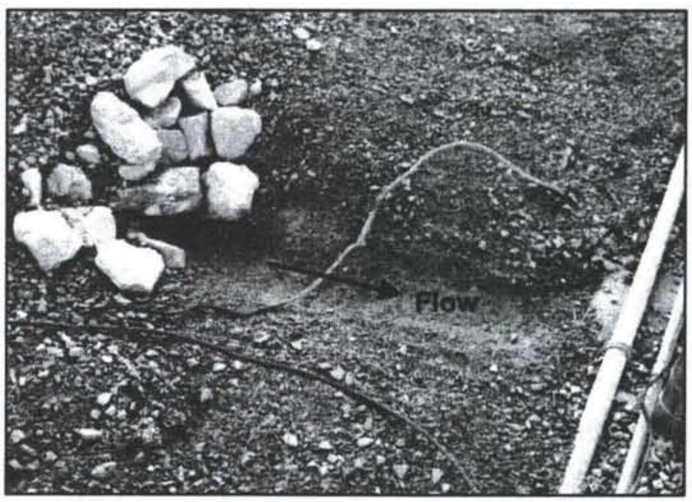


Figure 2.5 Photograph of Unit 2 Moat Drainage to Ground Surface

5. Modularized Transfer Demineralization System (MFTDS) Release to Railroad Bay – May 19, 1997

Due to failure of the conductivity probe on the MFTDS, approximately 3,000 gallons of water was released to the 706 ft-msl elevation Railroad Bay (Figure 2.6). It was estimated that 600-1000 gallons of water was released to the RadWaste Yard immediately adjacent to the Railroad Bay door. Problem Evaluation Report (PER) No. SQ971429PER was initiated to investigate the release. A subsequent report (Smith, 1997) addresses cleanup at the site.

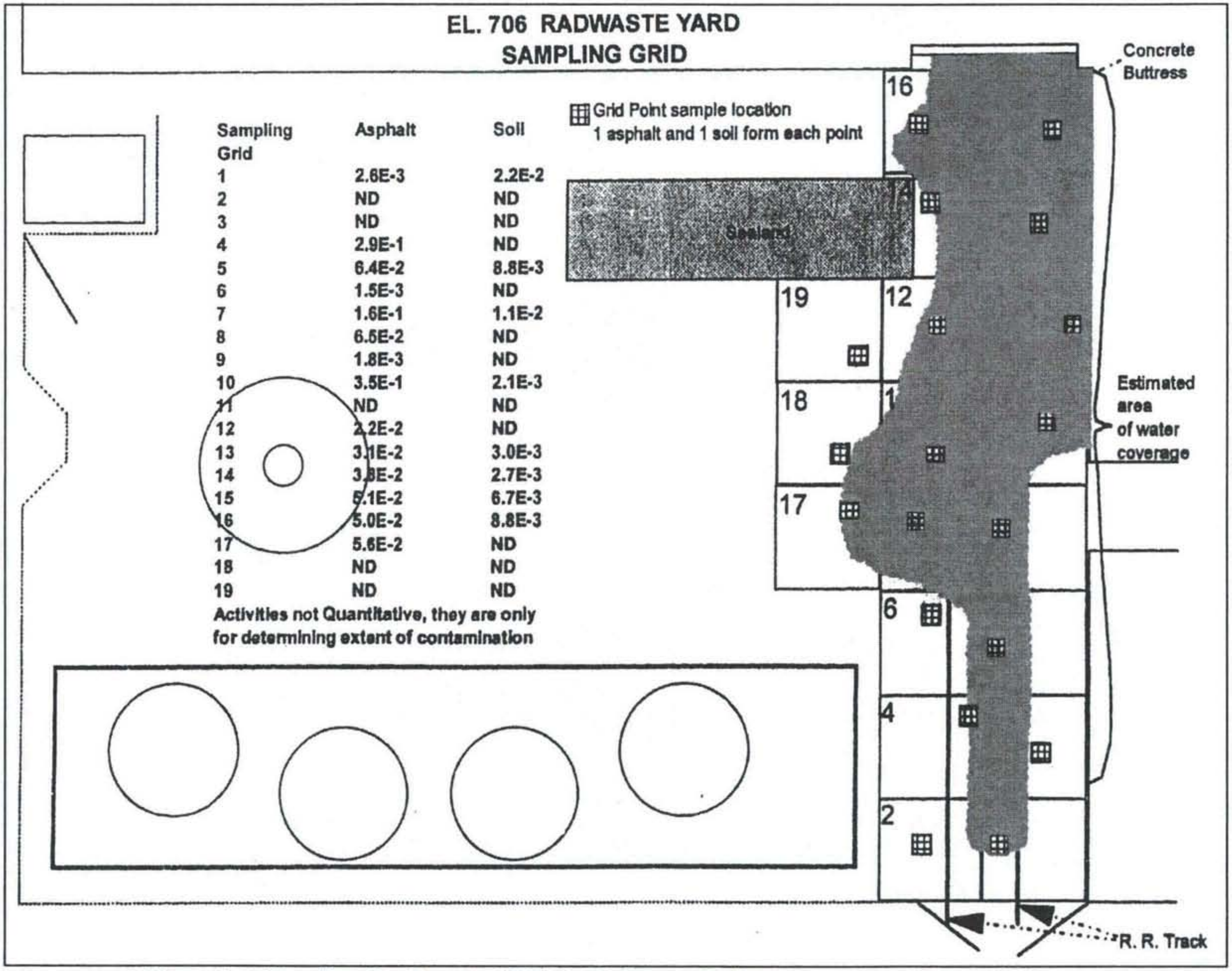


Figure 2.6 Map Showing Extent of MFTDS Release to Railroad Bay (from Halter, 1997)

Smith (1997) indicates that the water spill was observed to spread over a 950 ft^2 asphalted area. The initial response also noted a vortex near railroad ties within the release area. Subsequent investigation revealed a French drain system parallel to both sides of the existing railroad track and extending outside of the Radiation Control Area (RCA). Soils samples were collected and select isotopes (Co-57, Co-58, Co-60, Cs-134, Cs-137, Nb-95, and Mn-54) were screened to 5.0E-07 μCi/g. Results indicated radioactive contamination at and below the French drain system for several soil samples.

Asphalt and soil were excavated beginning June 6, 1997. Approximately 200 ft^3 of uncontaminated asphalt and 2000 ft^3 of uncontaminated soil were removed outside of the RCA. About 1000 ft^3 of contaminated soil, sand, and gravel were also excavated outside of the RCA. Smith (1997) notes that there were no attempts to remove concrete containing electrical conduit banks that were observed to be contaminated. There were also culverts observed with inaccessible contaminated sand that were not removed. The excavated French drain outside of the RCA was backfilled with concrete.

Excavation of the affected are inside of the RCA resulted in about 5500 ft^3 of radioactive contaminated asphalt, soil, sand, and gravel. The excavation area was 18 x 54 ft with excavation depth being limited by a concrete pad about 3-ft below ground surface. This and other concrete supports within the RCA were not disturbed and residual radioactive is accounted for in Smith (1997). The excavated area within the RCA was backfilled with concrete.

Quarterly surveys (RMD-FO-35) were subsequently performed by Radiation Protection.

6. *Unit 2 Additional Equipment Building (Upper Head Injection) Sump Release – January 10, 1998*

The Unit 2 Additional Equipment Building sump overflowed, exited the double-doors, and continued along a straight-line route (110 linear ft) to the nearest storm drain catch basin (Figure 2.7). The response team observed released water flowing into the catch basin. Sampling confirmed radioactivity in asphalt and soil leading to the catch basin. Water samples collected at the catch basin and at the storm drain discharge to the Yard Drainage Pond did not identify the presence of radioactivity. A water sample collected inside the building indicated Xe-133 to be the dominant radionuclide. A total of 32 soil samples were collected before and during excavation and sample analyses included a peak search for the Xe-133 energy peak. All results were negative. Select isotopes (Co-58, Co-60, Cs-134, and Cs-137) were also used to screen soil samples to 5.0E-07 μCi/g during excavation. Sediment samples from the release area catch basin contained C0-60 and Co-58 at 8.65E-07 and 5.99E-07 μCi/g, respectively.

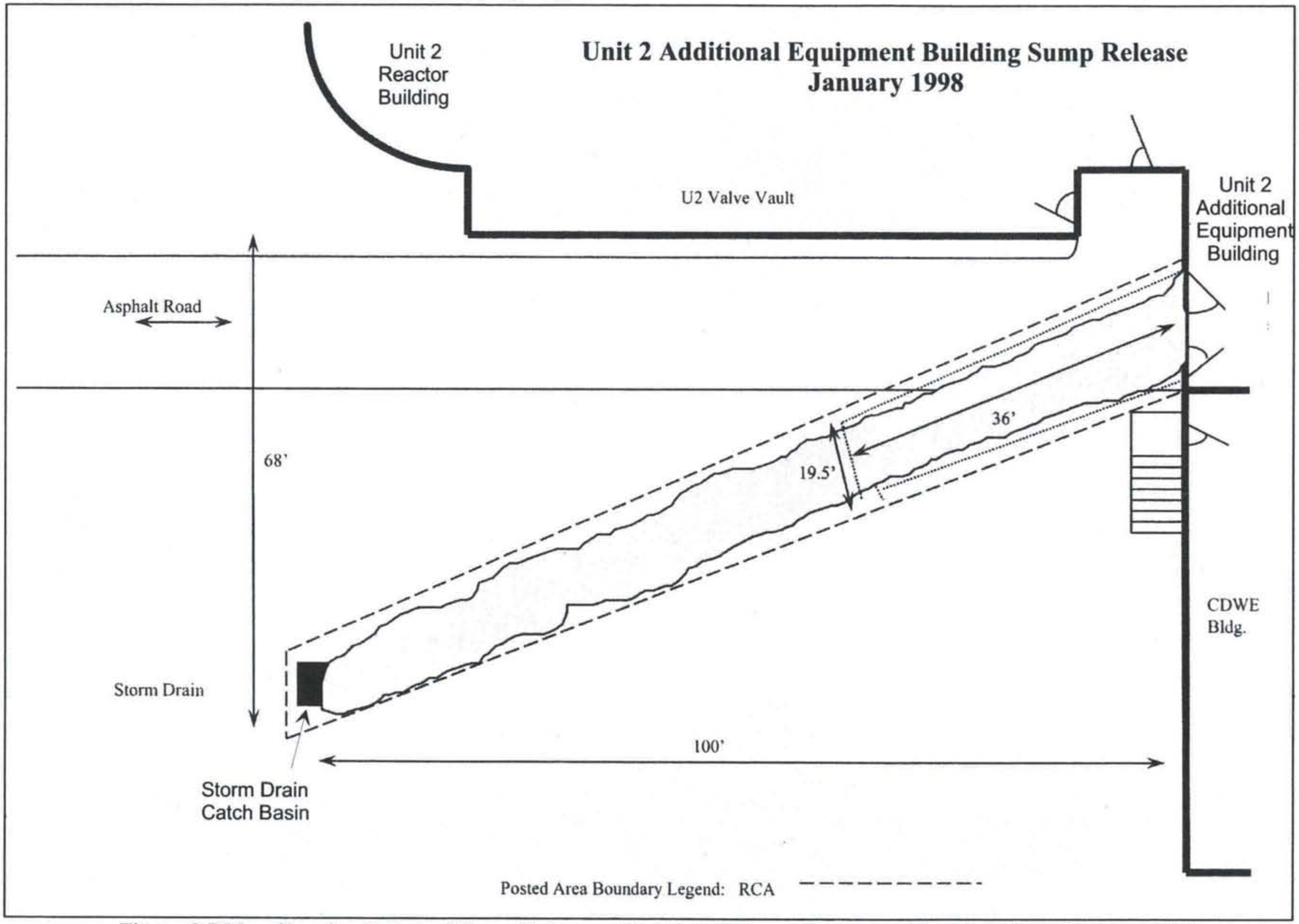


Figure 2.7 Map Showing Extent of Sump Release at Unit 2 Additional Equipment Building (from Halter, 1998)

A recovery report by Halter (1998) described remediation associated with this release. Decontamination of the Additional Equipment Building was initiated on January 10, 1998. Three additional storm drain catch basins were identified for sampling no gamma energy peaks were identified from gamma spectroscopy analyses. The asphalt layer immediately outside of the door was removed. Excavation of gravel and soil along the release route varied from 4 to 10 inches in depth and averaged about 19.5 ft in width. A total of 2070 ft^3 of excavated material was removed and replaced with aggregate material. Figure 2.8 provides photographs of the recovery area. As shown in this figure, groundwater monitoring well W21 is located within the drainage route of the released water.

Quarterly surveys (RMD-FO-35) were subsequently performed by Radiation Protection.

7. *Unit 1 Refueling Water Storage Tank (RWST) Moat Drain – April 3, 2002*

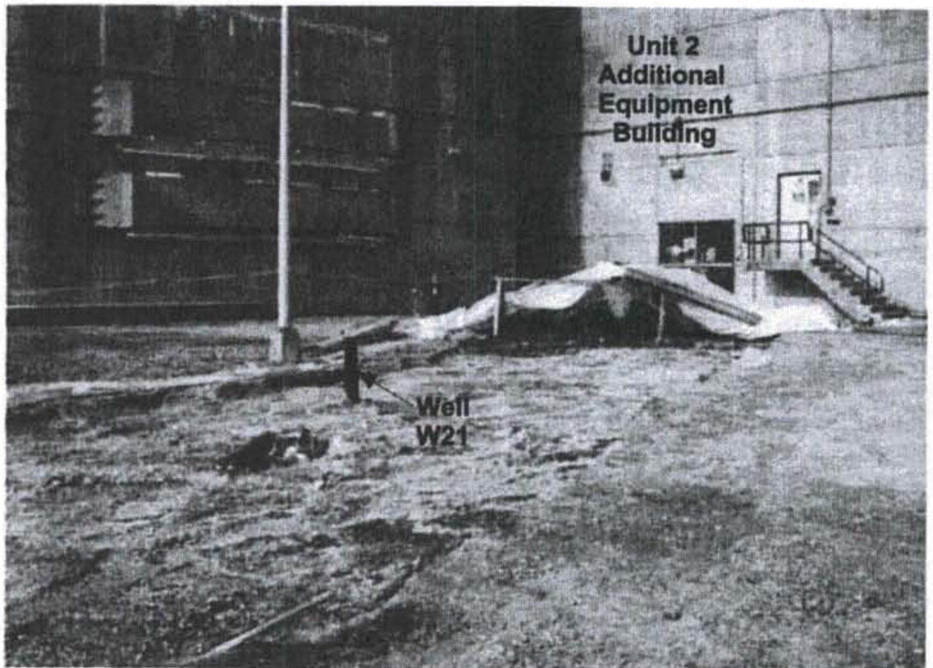
Pre-excavation samples of the steam generator replacement crane foundation identified radioactivity in soil surrounding the Unit 1 RWST moat drain. The drain outlet is located on the west side of the moat, extending through a retaining wall and discharging to an asphalt parking area (Figure 2.9). Soil sampling was performed and radioactivity (Mn-54, C0-57, Co-58, Co-60, SB-125, Cs-134, and Cs-137) was identified in eleven shallow soil samples in excess of the MDCs. Seventeen additional soil samples were collected in August 2002 gamma scans indicated no activity for all samples. Documentation includes a drawing of sample locations with attached sample gamma analysis results from WARL.

Quarterly surveys (RMD-FO-35) were subsequently performed by Radiation Protection.

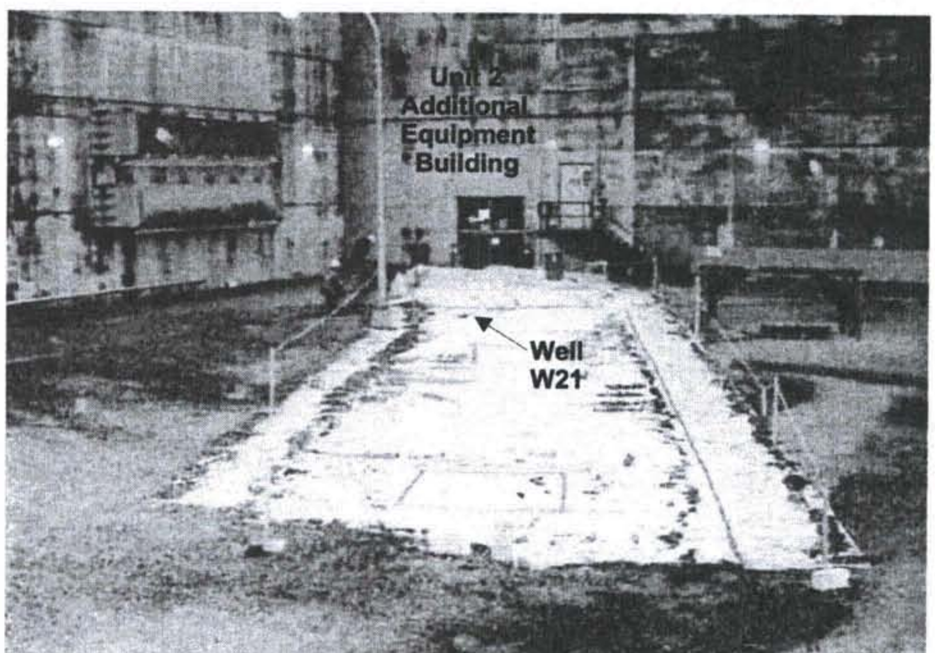
8. *Tritium in Unit 1 and 2 RWST Moat Collected Rainwater – July 17, 2006*

Each of the Unit 1 and 2 RWST moats is open to the collection of rainfall. This design differs from other plants such as WBN where permanent covers are installed to direct precipitation away from the moats. Per team discussions at the onset of this investigation, chemistry surveillance instruction 0-SI-CEM-040-421.0 was revised during the first quarter of 2006 to require tritium analysis of moat water. This revision also includes a requirement for discharge of Unit 2 moat water to either the Auxiliary Building RadWaste System or the Turbine Building Sump.

RWST moat water samples were collected July 11, 2006 and tritium concentrations of 517 and 19.5 pCi/mL were observed for Units 1 and 2, respectively. Documentation includes a memorandum by Halter (2006) describing operations, sampling, tritium results, and photographs.



Excavated Area



Release Area Covered with Plastic

Figure 2.8 Photographs of Sump Release Area at Unit 2 Additional Equipment Building (from Halter, 1998)

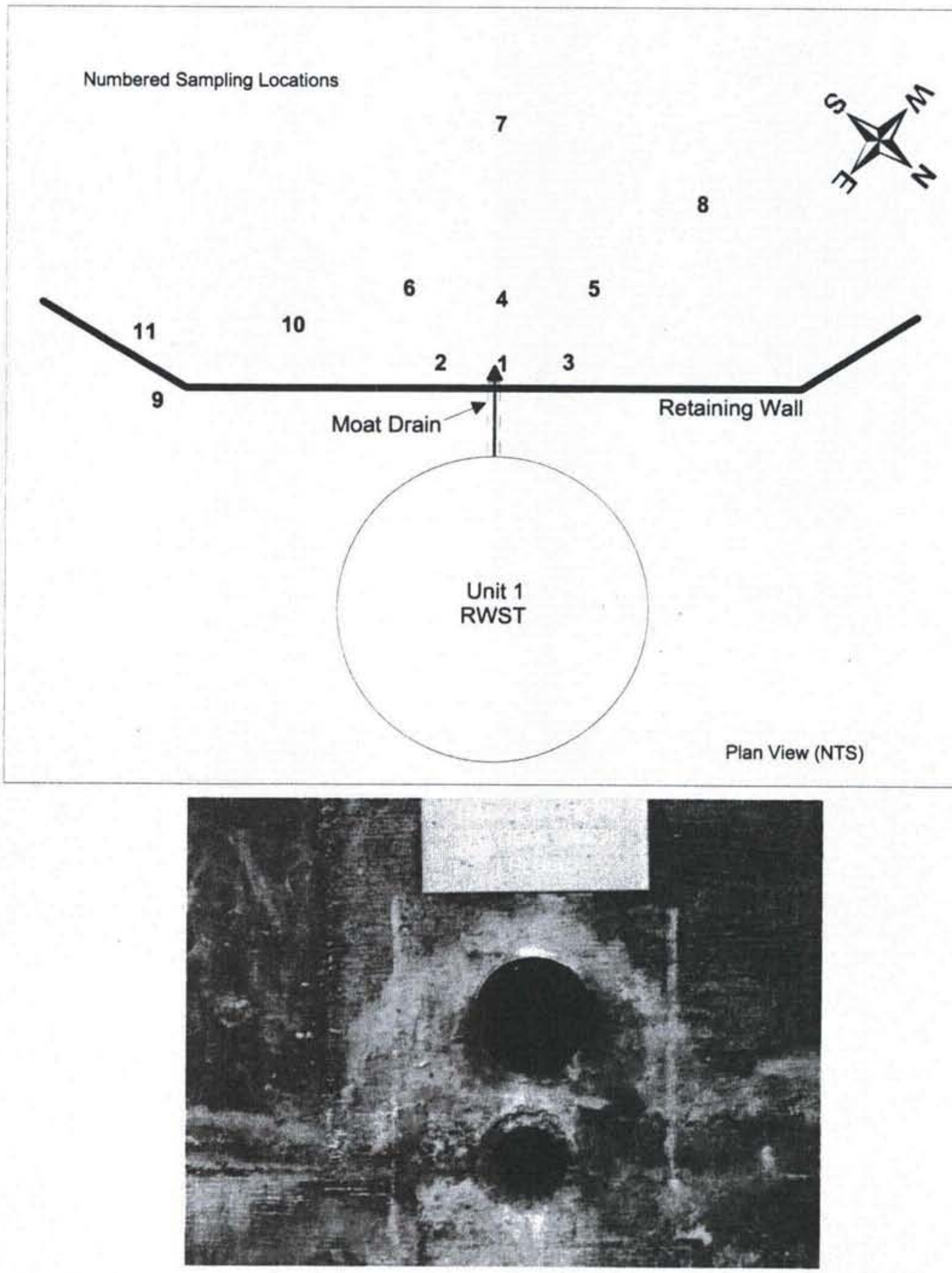


Figure 2.9 Schematic of Sampling Locations and Photograph of Unit 1 RWST Moat Drain

3.0 HYDROGEOLOGY

3.1 Site Location and Scope of Exploration

The SQN site is situated on a peninsula extending from the western bank into Chickamauga Lake between TRM 484 and 485 (Figure 3.1).

Pre-operational subsurface investigations of the site began in 1953. Figure 3.2 depicts the locations of exploratory borings installed at the site during these investigations. Twenty-nine holes were drilled into rock while seventeen were fishtailed to the top of sound rock. From September 1968 to February 1969, additional holes were drilled to fill in a 100-foot grid in the Control and Auxiliary Building area, and in the reactor areas, with holes drilled at the intake structure and other locations in the general plant area. In addition to obtaining information on the foundation conditions, the holes in the reactor areas were used for dynamic seismic investigations. During September and October 1969, a third drilling program was carried out to further investigate the reactor, control, and auxiliary areas on a 50-foot spacing, and to examine the condition of the Kingston fault northwest of the plant site (TVA, 2005).

Post-operational subsurface investigations at the site have been conducted to resolve contaminant release issues and for siting of new facilities. Edwards et al. (1993) and Julian (1993) installed 21 soil borings and 9 groundwater monitoring wells to assess No. 2 Diesel Fuel Oil contamination from underground transfer lines. Julian (2000) conducted a groundwater supply study that included review of groundwater supply wells located in the vicinity of SQN. Siting for the Independent Spent Fuel Storage Installation (TVA, November 2001) involved the installation of three monitoring wells and numerous shallow borings to assess petroleum contamination (TVA, June and September 2001). From February 2002 – April 2004, 12 shallow groundwater monitoring wells were installed for evaluations of tritium releases from the 6- and 12-inch waste condensate lines.

Soil borings and wells installed as part of this tritium investigation are described in following paragraphs.

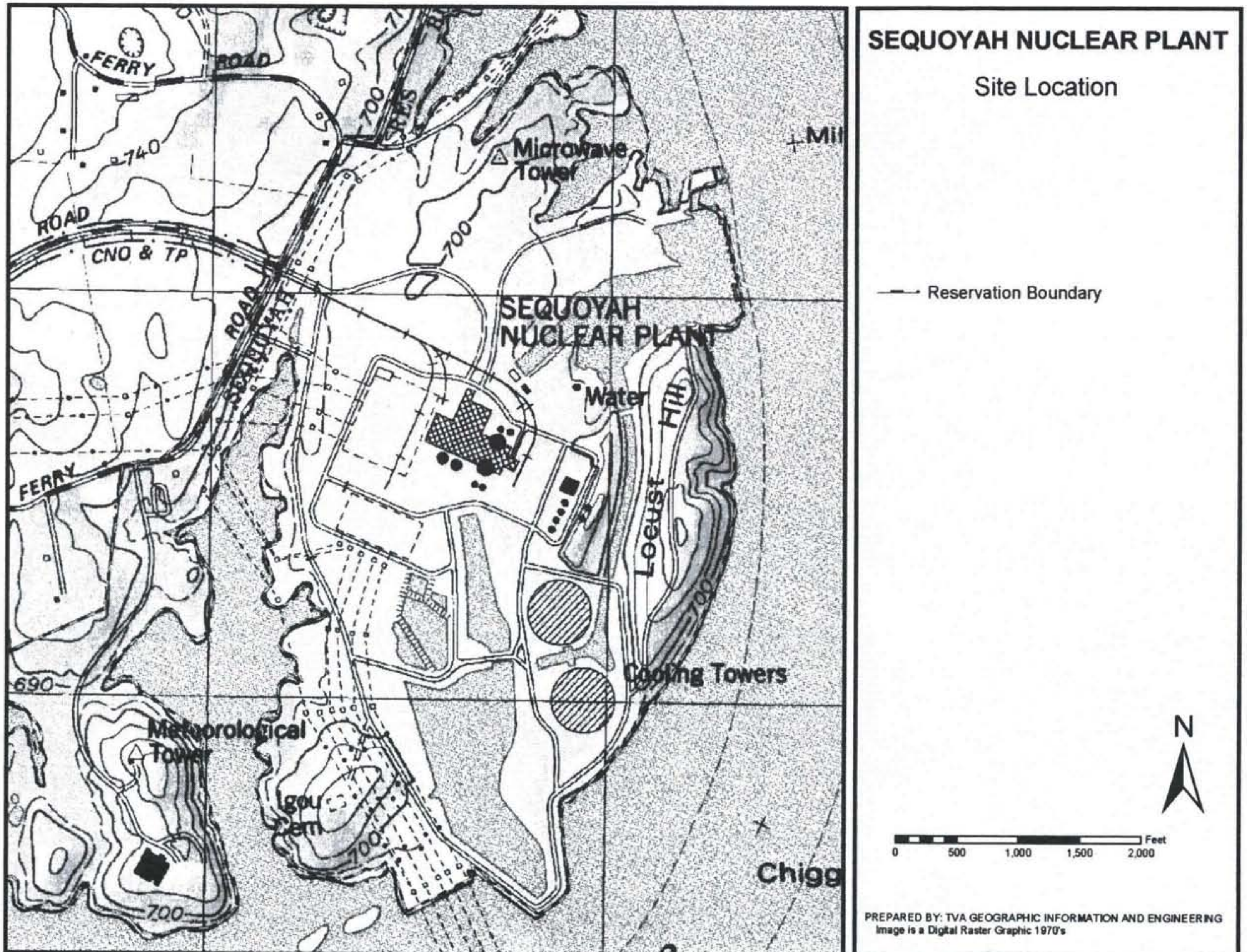


Figure 3.1 Site Location Map

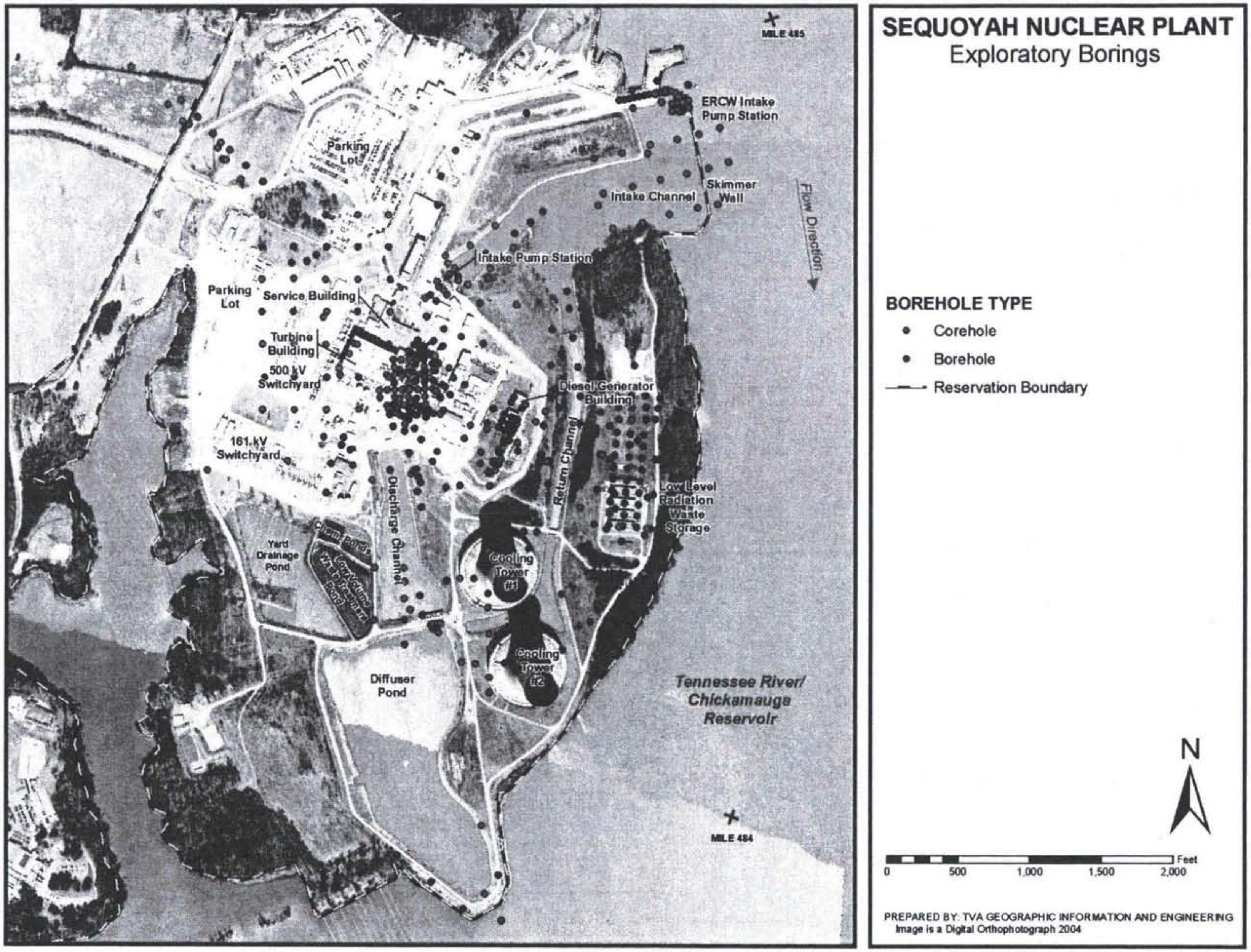


Figure 3.2 Locations of Exploratory Borings

3.2 Physiography

The Valley and Ridge Province is a long narrow belt trending NE-SW that is bordered by the Appalachian Plateau on the west and by the Blue Ridge Province on the east. Geochronologically, this province represents the eastern margin of the Paleozoic interior sea. Structurally, it is part of an anticlinorium, the successor to a geosyncline that sank intermittently for ages as it received sediments from the concurrent rising land surface on the east. The topographic and geologic grain of this subregion is elongated NE-SW in conformity with the trend of the Appalachians region. Viewed empirically, the province is a lowland; an assemblage of long, narrow, fairly even-topped mountain ridges separated by somewhat broader valleys. The ridges are developed in areas underlain by resistant sandstones and more siliceous limestones and dolomites. The valleys have been developed along structural lines in the areas underlain by easily weathered shales and more soluble limestones and dolomites.

Prior to the impoundment of Chickamauga Reservoir, the Tennessee River in the vicinity of SQN had entrenched its course to elevation 640. The small tributary valley floors slope from the river up to around elevation 800 ft-msl, while the crests of the intervening ridges range between 900 and 1000 ft-msl.

Figure 3.3 shows topography at SQN. The majority of the plant site resides at a grade elevation of 705 ft-msl. Elsewhere, terrain is rolling with the highest elevation of about 775 being encountered southeast of the plant site at the top of Locust Hill (LLRWSF site).

3.3 Geomorphology

The SQN site resides near the western border of what was the active part of the Appalachian geosyncline during most of the Paleozoic era. During this time, the area was below sea level and more than 20,000 feet of sedimentary rocks were deposited. At the end of the Paleozoic era, some 250 million years ago, the area was uplifted and subjected to compressive forces acting from the southeast. Folds developed which were compressed tightly, overturned to the northwest, and finally broken by thrust faults along their axial planes. The resultant structure is characterized by a series of overlapping linear fault blocks which dip to the southeast. Since this period of uplift, the area has been subjected to numerous cycles of erosion. This erosion accentuated the underlying geologic structure by differential weathering of the less resistant strata resulting in the development of parallel ridges and valleys which are characteristic of the region.

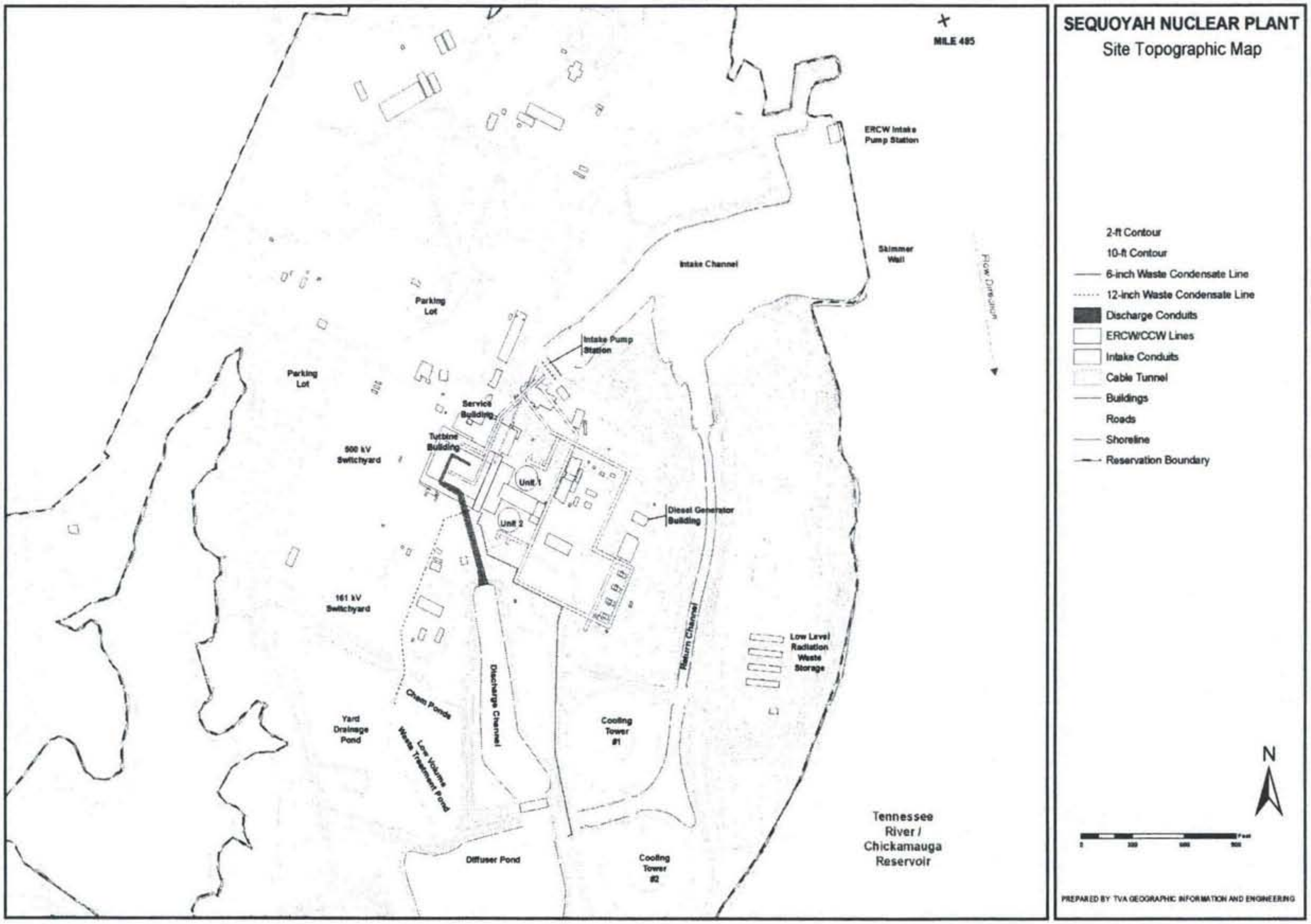


Figure 3.3 Site Topographic Map

3.4 Geology

3.4.1 Stratigraphy

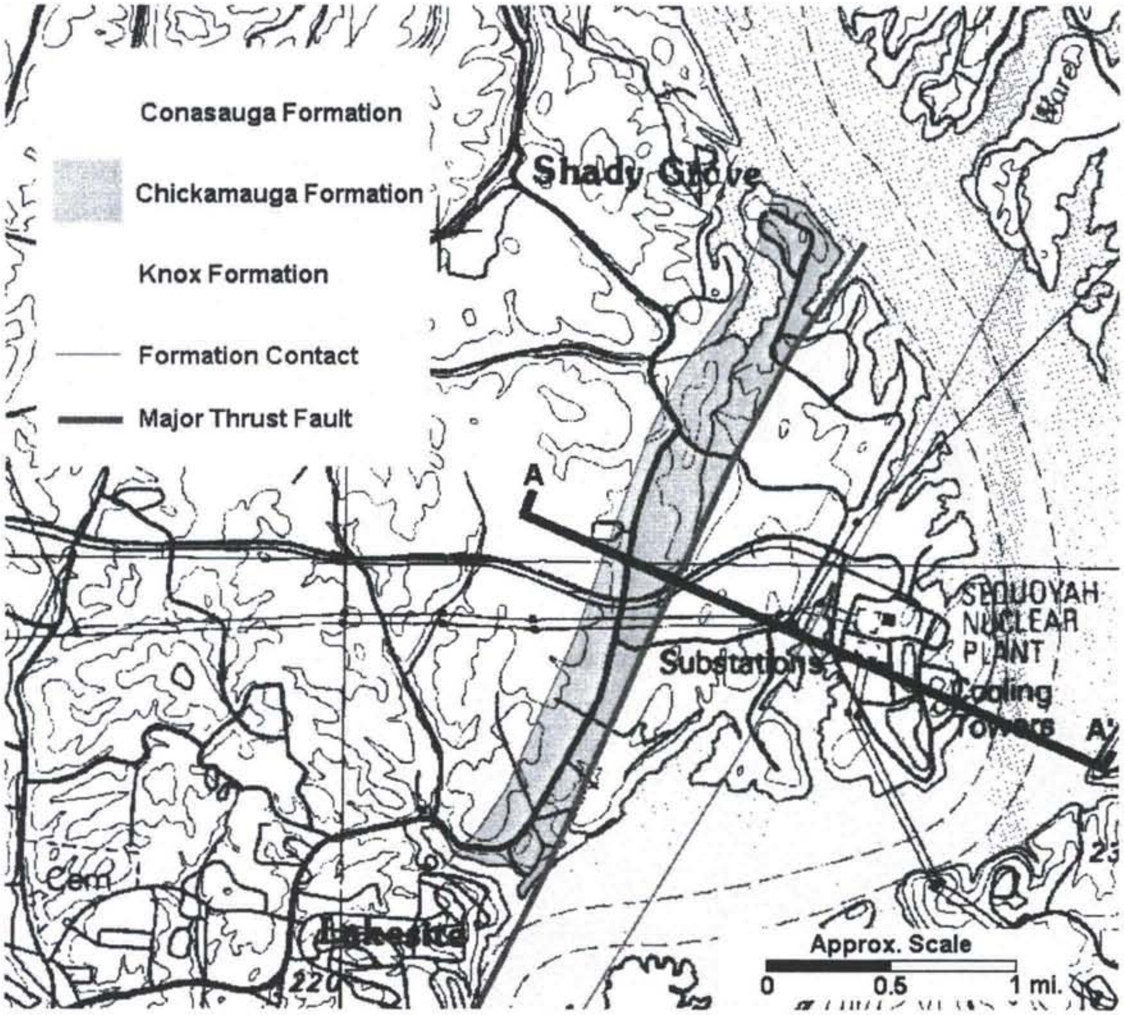
Of the numerous sedimentary formations of Paleozoic age in the plant area, only the Conasauga Formation of Middle Cambrian age is directly involved in the foundation bedrock of the plant (Figure 3.4). Unconsolidated alluvial, terrace, and residual deposits mantle the Conasauga formation at the site. More recent alluvial deposits, that were associated with the floodplain of the Tennessee River, are now covered by the Chickamauga Reservoir.

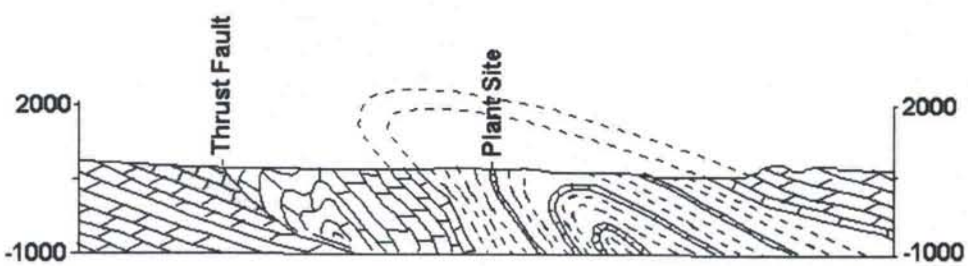
3.4.2 Bedrock

The Conasauga formation at the site is composed of several hundred feet of interbedded limestone and shale in varying proportions. The shale, where fresh and unweathered, is dark gray, banded, and somewhat fissile in character. The limestone is predominantly light gray, medium grained to coarse crystalline to oolitic, with many shaly partings. A statistical analysis of the cores obtained from the site area indicates a ratio of 56 percent shale to 44 percent limestone. Farther to the southeast and higher in the geologic section, the amount of limestone increases in exposures along the shore of the reservoir.

The general strike of the Conasauga is N30°E and the overall dip is to the southeast, normally steep, ranging from 60° to vertical; however, many small, tightly folded, steeply pitching anticlines and synclines result in local variations to the normal trend.

According to TVA (1979), cavities and solution openings are not a major problem in the site foundation. Most solution openings are restricted to the upper few feet of bedrock near the overburden/bedrock interface. The insolubility of interbedded shale in deeper bedrock functions as a lithologic control to the development of large solution openings. However, small solution openings and partings may exist at greater depths within the bedrock along faults and joints, especially along synclinal zones. Inspection of the walls of the exploratory holes with television disclosed thin, less than 0.05 foot, near-horizontal openings in some of the limestone beds. At the corresponding position, the drill cores showed unweathered breaks. These open partings are interpreted as "relief joints" developed by unloading either from erosion or excavation. The majority was found in the upper few feet of rock, but some were observed as deep as 131 feet below the rock surface.





Section A - A'
(not to scale)

Figure 3.4 Regional Map Showing Geologic Formations and Structure

Figure 3.5 shows the Conasauga bedrock surface based on all available site boring data. As would be expected in a foundation composed of alternating strata of different composition and competency, the configuration of the bedrock surface is irregular (TVA, 1979). The strike of the rock strata is approximately parallel to the centerline of the reactors. Preliminary excavation for foundation investigations (down to 18 inches above design grade) exposed a series of alternating ridges of harder limestone separated by troughs underlain by the softer shale trending across the plant area. The last 18 inches were removed by careful and controlled means so as to limit breakage below the design grade to a minimum. Once foundation grade was reached, the area was carefully cleaned and then inspected jointly by engineers and geologists to determine what, if any, additional material needed to be removed because of weathering or shattering by blasting. Figure 3.6 exemplifies top of rock exposed in the Reactor, Auxiliary, Control, and Turbine Buildings prior to excavation.

After the final excavation was approved, the area was covered either by a coating of thick grout or by a fill pour of concrete to prevent weathering of the shale interbeds due to prolonged exposure. Observation of rock exposed in the foundation areas, examination of cores, and investigations of the walls of exploratory holes with a borehole television camera all indicated that solution cavities or caves are not a major problem in the foundation. Verified cavities generally were limited to the upper few feet or rock where solution developed in limestone beds near the overburden-rock interface. Practically all of this zone was above design grade and was removed.

A consolidation grouting program was performed from February 18 through June 15, 1970 in the foundation areas for the Reactor, Auxiliary, and Control Buildings at the Sequoyah Nuclear Plant. The extent of the area treated is shown in TVA (2005; Figures 2.5.1-9 and 2.5.1-10). The purpose of this program was twofold. The first was to consolidate near-surface fractures predominantly caused by blasting and excavation. The second was to treat any localized open joints, bedding planes, fractures, or isolated small cavities that pre-construction exploratory drilling indicated might be present to a depth of 45 feet below the design foundation grade.

In the excavated area, the contact between the residual material and essentially unweathered rock occurs at an average elevation of 680 ft-msl. The highest design level for the plant foundation grade under the Class I structures is at elevation 665 ft-msl. As a result, the preliminary excavation averaged a minimum of 15 feet in rock. Over most of the area, the rock was suitable for foundation purposes at elevation 665 ft-msl.

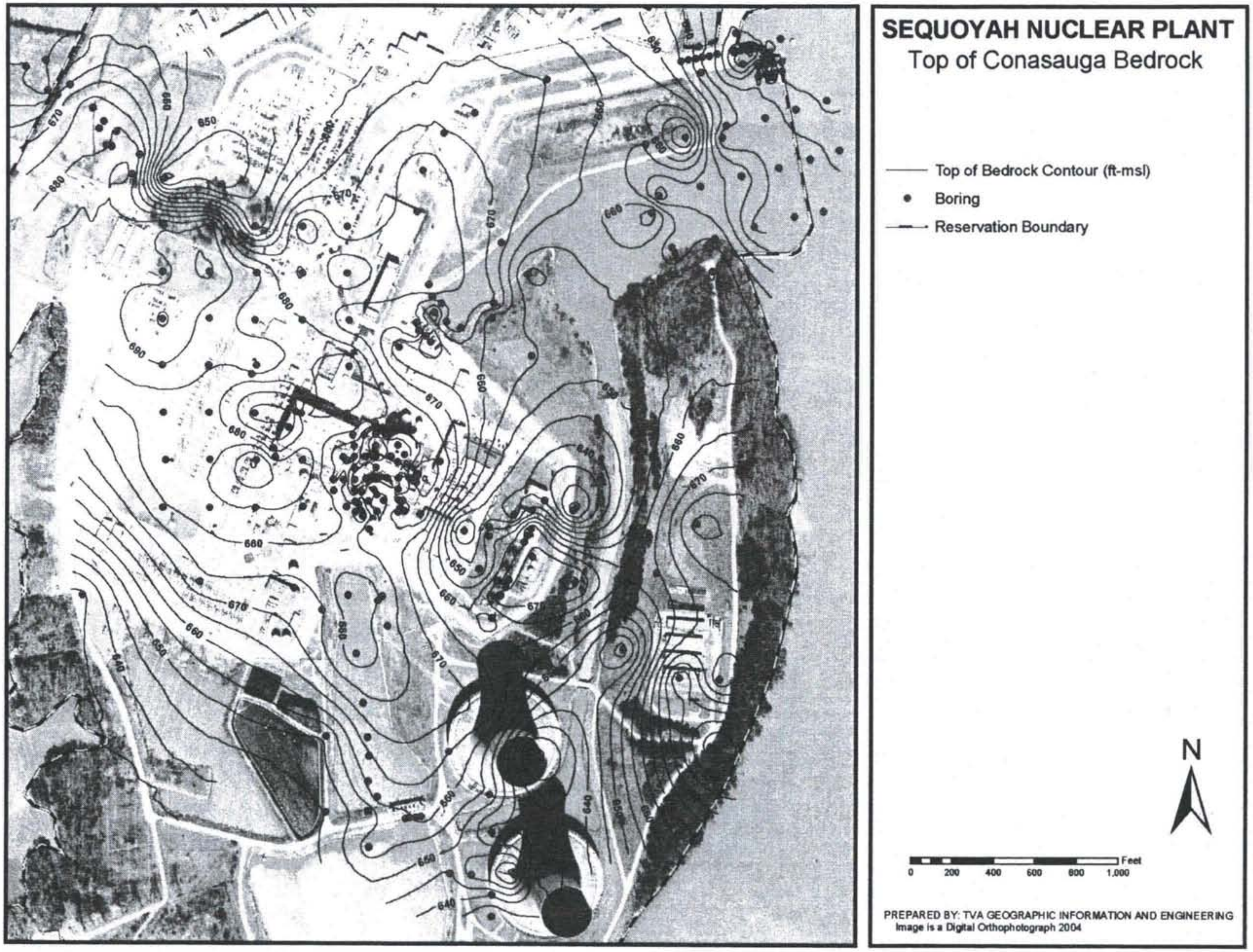


Figure 3.5 Surface of Conasauga Bedrock

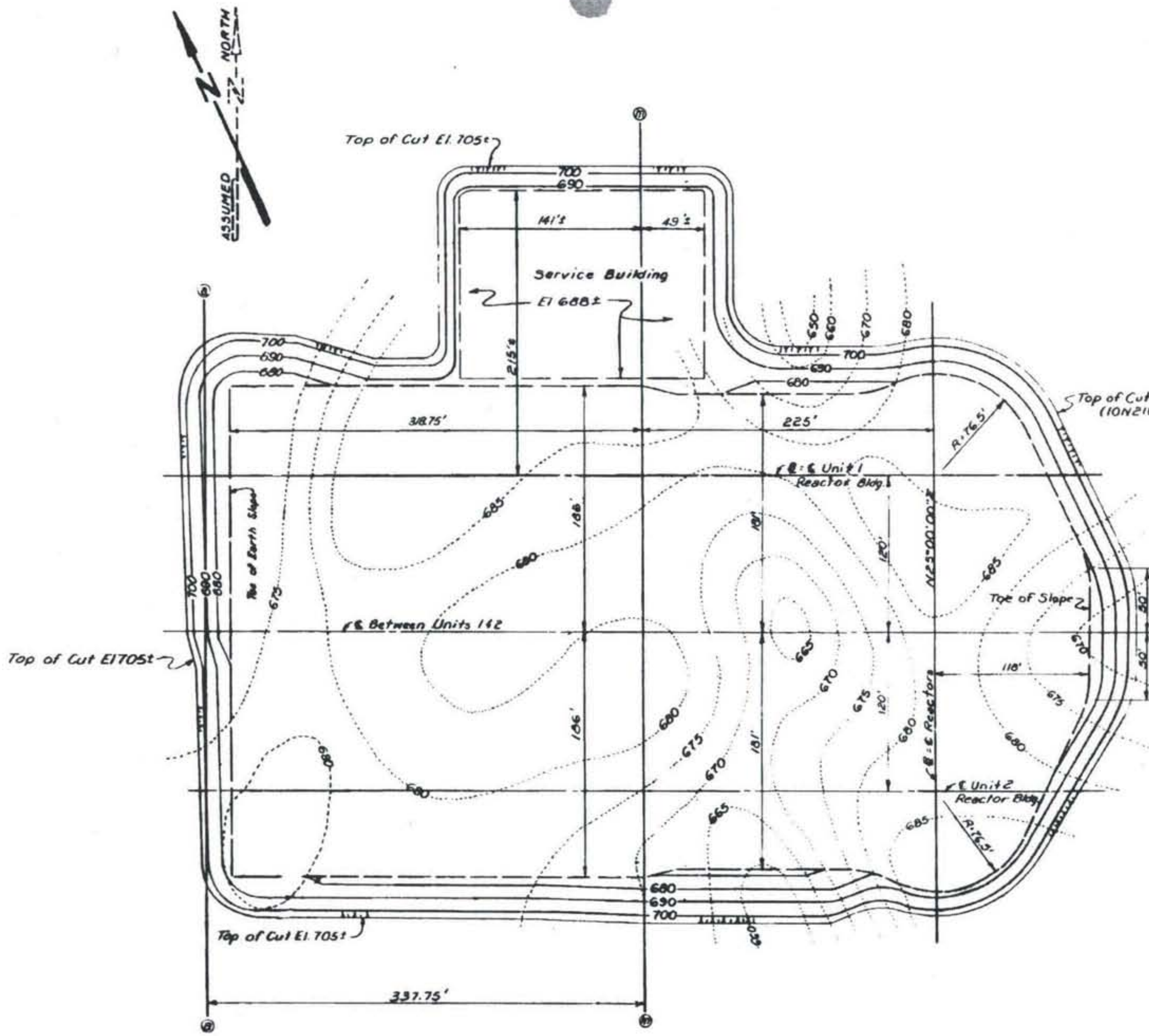


Figure 3.6 Pre-excavation Top of Bedrock Contours (ft-msl) at the Reactor, Auxiliary, Control, and Turbine Buildings (from TVA Drawing 10N211)

In two areas, however, additional rock had to be excavated to remove localized pockets of deeper weathering. These zones were confined in two synclinal areas which crossed the excavation parallel with the north- south baseline. The axis of one lies approximately 70 feet plant east of the baseline and the axis of the other is approximately 140 feet plant west of the baseline. These trough-like synclines had channeled groundwater movement toward and along their axes with the result that weathering had progressed deeper in these areas. Generally, less than 10 feet of additional rock had to be removed from the synclinal zones to obtain a satisfactory foundation; however, in the vicinity of W140; S 220, on the south side of the Auxiliary Building, as much as 30 feet of weathered rock was removed.

3.4.3 Soil

Unconsolidated alluvial, terrace, and residual deposits mantle the Conasauga formation at the site. More recent alluvial deposits that were associated with the floodplain of the Tennessee River are now covered by the Chickamauga Reservoir. Alluvium within the area of the main plant site was removed during construction and only residual soils remain. In the plant area not mantled by terrace deposits, the Conasauga is overlain by varying thicknesses of residual silt and clay derived from weathering of the underlying shale and limestone. The residual soils are primarily silts and clays grading downward into saprolitic shale of the Conasauga. In a few localized areas weathered shale is exposed at the ground surface. However, in most exploratory drilling the residuum depths ranged from 3 to 34 ft.

A pre-construction soils exploration program was conducted at the plant site to determine the static physical characteristics of the soils. Standard split-spoon borings and undisturbed borings were made. Grain size analyses shows that soils across the site range from fat clay residual material to sand and gravel terrace deposits.

The age of unconsolidated material at SQN is in excess of 30,000 years. No carbonaceous soil was encountered in site excavation and no other dating criteria could be established (TVA, 1979). Carbon 14 dates from material found in high alluvial terrace deposits at the Watts Bar Nuclear Plant located about 38 miles northeast of Sequoyah placed the age of the material at 32,400 years.

Terrace deposits overlie residuum with varying thickness across the site. Terrace material consists predominantly of sandy clay with embedded rounded cobbles and pebbles of quartzite, quartz and chert. This material represents deposition at a time when the river was flowing at a higher elevation during an earlier erosion cycle. According to TVA (1979), a maximum thickness of 45 feet of terrace deposits was encountered in exploratory drilling in the topographically high areas southeast of the site, and it is quite probable that greater thicknesses exist under the highest portion of this area (i.e., Locust Hill). Evidence suggests that residual material has essentially been eroded away under Locust Hill with terrace deposits directly overlying bedrock. This hill is the location of the LLRWSF.

Based upon more extensive borings, Boggs (1982) describes the Low Level Radwaste Storage Facility (LLRWSF) site as being underlain by residual and alluvial soils generally consisting of clay and silt with minor amounts of sand and gravel. According to Boggs (1982), soil thickness averages about 50 feet within the LLRWSF area, but varies radically over short distances due to a highly irregular bedrock surface configuration. Fill/spoil material was also used as foundation material beneath the LLRWSF.

In situ soil dynamic studies were made at the plant site to obtain data for computation of elastic moduli for earthquake design criteria. The areas investigated at the site were the Diesel Generator Building, the LLRWSFs, the ERCW pipeline, the Additional Diesel Generator Building, and the Primary Water Storage Tank.

Prior to and during construction, borrow investigations were made on an as-needed basis. The borrow samples were tested by the central materials laboratory according to ASTM D-698 to develop compaction control curves. The compaction curves were divided into subclasses to control compaction of earthfill at the site. At SQN, Type A backfill (sandy to silty clay) was placed around all Category I structures. This material, which was selected earth placed in not more than 6-inch layers, has a minimum required compaction of 95 percent of the maximum dry density at optimum moisture content. The limits of excavation and the backfill around Category I structures can be visualized in Figure 3.7.

A free-draining granular fill material, consisting of crushed stone or sand and gravel, was placed below or next to Category I structures. This material was obtained commercially from off-site sources. The granular fill was suitable for compaction to a dense, stable mass and consisted of sound, durable particles which are graded within the following limits:

	Percent by Weight	
Passing	**Minimum**	**Maximum**
1¼-inch	100	
1-inch	95	100
¾-inch	70	100
⅜-inch	50	85
No. 4	33	65
No. 10	20	45
No. 40	8	25
No. 200	0	10

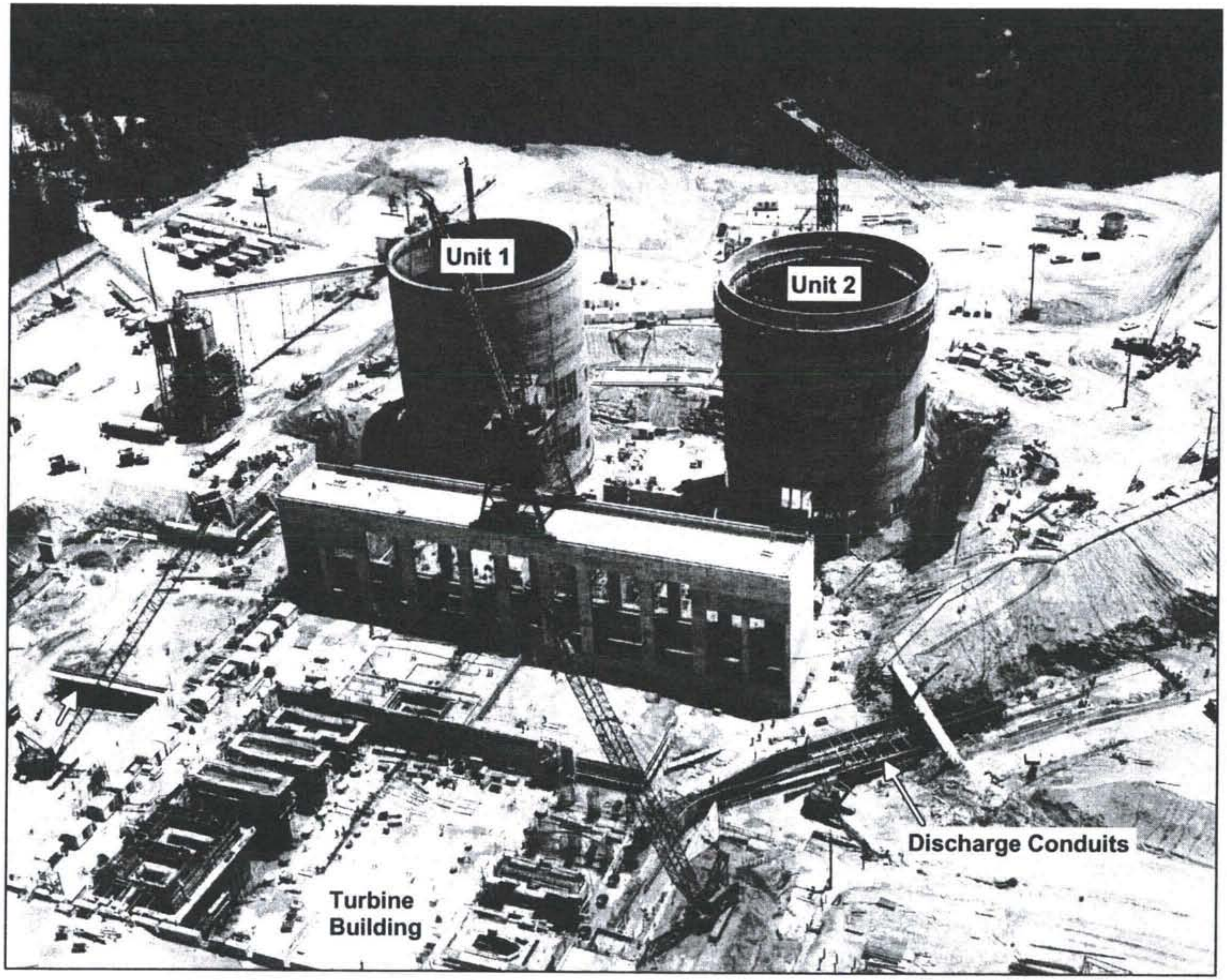


Figure 3.7 1971 Site Construction Photograph of the Reactor, Auxiliary, Control, and Turbine Buildings

A crushed rock material that meets the gradation requirements shown below was used for remedial treatment in local areas. This was generally done where moisture caused the soil to be unsatisfactory as a base for earthfill placement. The material was used in a limited area at the RWST pipe tunnel. The material was placed in approximate 6-inch loose layers and rolled into the soil. If the required stiffness for the placement of earthfill was achieved, lifts of earth-fill or crushed stone fill were placed. If the required stiffness was not achieved, then additional lifts of the material were placed and rolled to obtain the desired stiffness. If shearing or pumping occurred in placement of the first lift, additional lifts of the material were placed as necessary.

	Percent by Weight	
Passing	**Minimum**	**Maximum**
3-inch	95	100
2-inch	25	55
1½-inch	0	15
1-inch	0	2

3.4.4 Structure

The controlling features of the geologic structure at the Sequoyah plant site are the Kingston Thrust fault (Figure 3.4) and a major overturned anticline that resulted from the movement along the fault. This fault lies about a mile northwest of the plant site (Figure 2.5.1-2), and can be traced for 75 miles northeastward and 70 miles southwestward. The fault dips to the southeast, under the plant site, and along it steeply dipping beds of the Knox dolomite have been thrust over gently dipping strata of the Chickamauga limestone. The distance from the plant site, about one mile, and the dip of the fault, 30 degrees or more, will carry the plane of the fault at least 2000 feet below the surface at the plant site.

The major overturned anticline results in the Conasauga formation at the plant site resting upon the underlying Knox dolomite which normally overlies it. As a result of the ancient structural movement of the fault and major fold, the Conasauga formation at the plant site is highly folded, complexly contorted, and cut by many very small subsidiary faults and shears. The general strike of these beds are N 30°E and the overall dip is to the southeast, but the many small tightly folded, steeply pitching anticlines and synclines result in many local variations to the normal trend.

In some of the drill cores, small faults and shears were noted intersecting the bedding at various angles. These dislocations are the result of shearing along the limbs of the minor folds which developed contemporaneously with the major movement along the Kingston fault.

3.5 Hydrology

The SQN site is in the eastern Tennessee portion of the Southern Appalachian region, which is dominated much of the year by the Azores-Bermuda anticyclonic circulation. This circulation over the southeastern United States is most pronounced in the fall and is accompanied by extended periods of fair weather and widespread atmospheric stagnation. In winter, the normal circulation pattern becomes diffuse as the eastward moving migratory high and low pressure systems, associated with the midlatitude westerly current, bring alternating cold and warm air masses into the area with resultant changes in wind direction, wind speed, atmospheric stability, precipitation, and other meteorological elements. In summer, the migratory systems are less frequent and less intense, and the area is under the dominance of the western edge of the Azores-Bermuda anticyclone with a warm moist air influx from the Atlantic Ocean and the Gulf of Mexico (TVA, 2005).

The climate of the watershed above SQN is humid temperate. All recharge to the groundwater system at the plant site is from local precipitation, which averages around 51 inches per year.

The Tennessee River above SQN site drains 20,650 mi^2. Chickamauga Dam, 13.5 miles downstream, and Watts Bar Dam upstream (TRM 529.9) affect water surface elevations at the Plant. Peaking hydropower operations of the dams cause short periods of zero and reverse flow near the plant. Based upon discharge records since closure of Chickamauga Dam in 1940, the average daily streamflow at the site is 32,600 cfs (TVA, 2005).

Chickamauga Reservoir water elevations vary seasonally according to operations for power production, navigation, and recreation. The operating guide for Chickamauga Dam is shown in Figure 3.8. As shown in Figure 3.9 elevations of the SQN Discharge Channel correlate with the operating guide. This is associated with plant operations during warmer months that are designed to comply with reservoir thermal release limits.

During high flow periods, the top of the normal operating zone may be exceeded for the regulation of flood flows. During the late spring and summer, TVA varies the elevation of Chickamauga Reservoir to aid in controlling mosquito populations. Elevations are lowered during the week and raised a foot on weekends, to strand mosquito eggs and larvae on the shoreline. Normal full pool elevation is 683.0 ft-msl. At this elevation, the reservoir is 58.9 miles long on the Tennessee River and 32 miles long on the Hiwassee River. The reservoir is approximately 3,000 feet wide at the site, with depths ranging from 12 feet to 50 feet at normal full pool elevation. Probable maximum flood elevation is 722.6 (TVA, 1979).

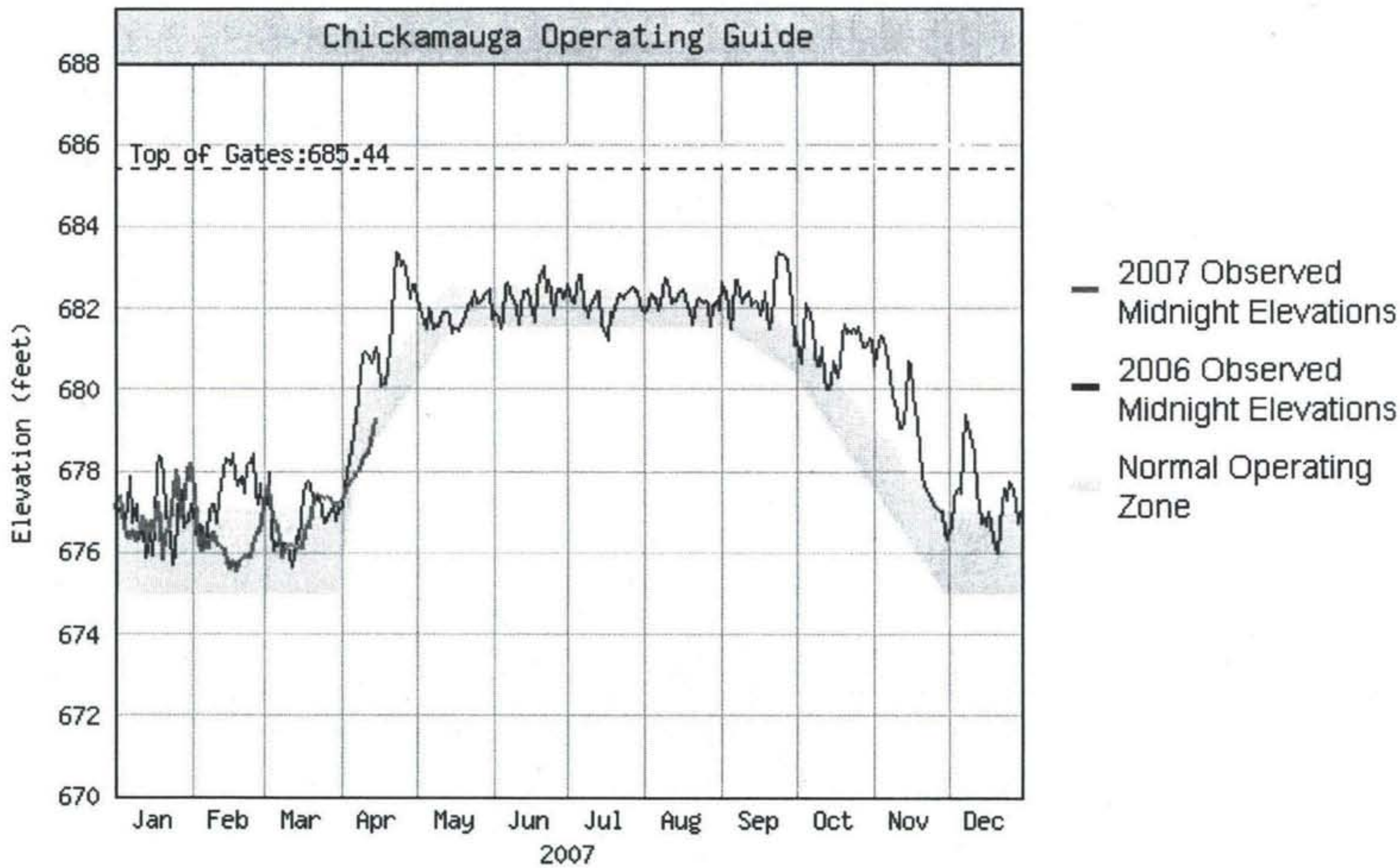


Figure 3.8 Operating Guide For Chickamauga Dam

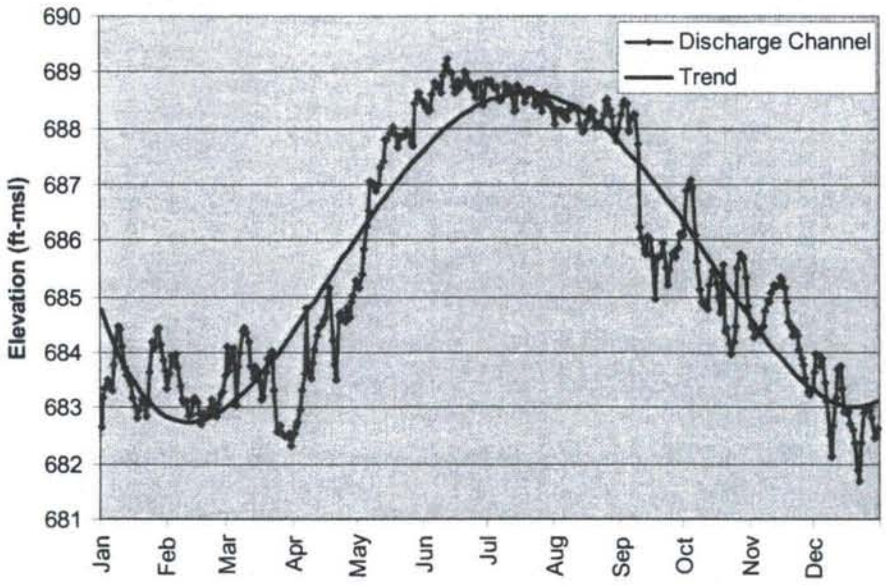


Figure 3.9 Mean 1995 – 1999 Discharge Channel Elevations

3.6 Groundwater

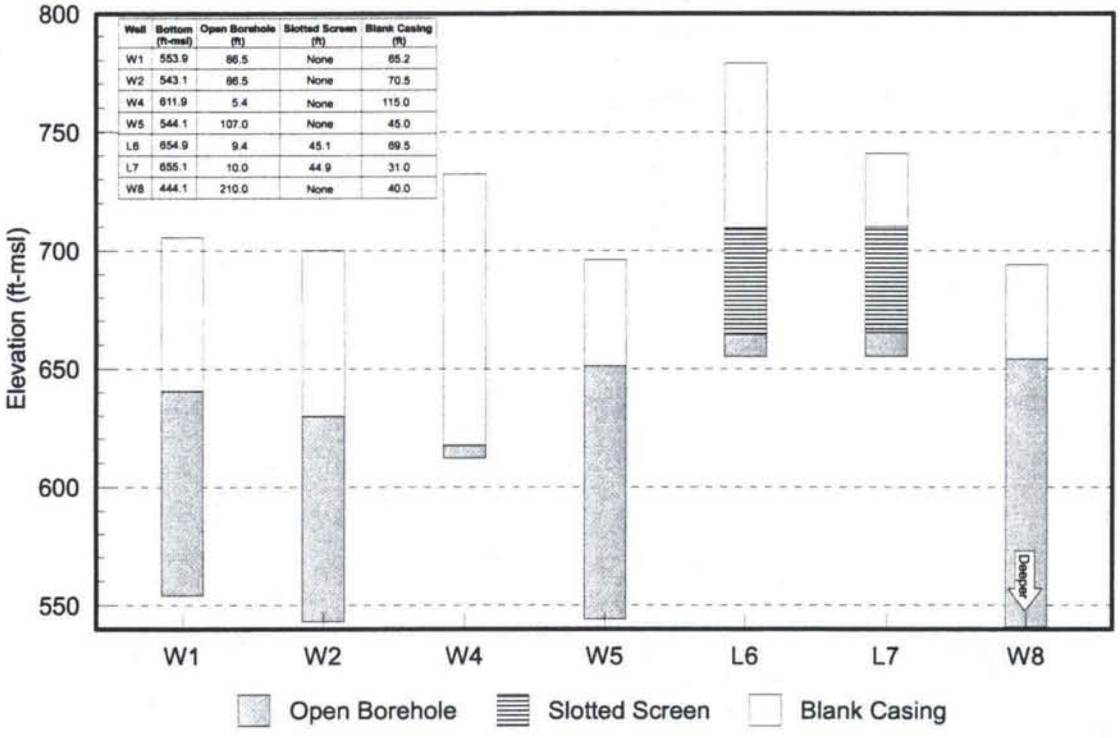
The peninsula on which SQN is located is underlain by the Conasauga, a poor water-bearing formation. About 2,000 feet northwest of the plant site, the trace of the Kingston Fault separates the Conasauga Shale from a wide belt of Knox Dolomite (Figure 3.4). The Knox is a major water-bearing formation of eastern Tennessee. Based on a comprehensive examination of bedrock coreholes (TVA, 1979), groundwater in the Conasauga occurs in small openings along fractures and bedding planes; these rapidly decrease in size with depth, and few openings exist below a depth of 300 feet.

There is no groundwater use at SQN. The source of groundwater at SQN is derived from incipient infiltration of precipitation. Within overburden soils at the site, groundwater movement is generally downward. Local areas of natural lateral flow likely occur near some streams, topographic lows, and where extensive root systems exist. Anomalous groundwater movement might also occur in areas that have experienced soil unraveling and in the vicinities of pipelines (especially those with relatively permeable bedding and fill).

Groundwater movement is expected to occur mainly along strike of bedrock, to the northeast and southwest, into Chickamauga Reservoir. Groundwater also discharges from overburden soils into the reservoir, site drainage channels (i.e., Discharge Channel), and surface water impoundments (i.e., Diffuser Pond). Higher surface water levels of Chickamauga Reservoir (April – October) result in corresponding rises in the groundwater table and the lateral extent of this effect varies with groundwater hydraulic gradients. Lower levels of Chickamauga Reservoir (November – March) result in corresponding declines in the water table along the reservoir periphery.

Pre-construction boring logs collected by TVA (1979) suggest that groundwater transmissivity across the strike in the Conasauga formation is extremely low. Local variations in hydraulic conductivity within the shallow bedrock are primarily controlled by geologic structure and stratigraphy. Shale beds and clay seams provide lithologic restrictions to the vertical movement of groundwater. The Conasauga/Knox contact northwest of the plant has been described as a hydraulic boundary; however, no field testing has been conducted to verify this assumption. Bedrock porosity is estimated to be about 3 percent based upon results of exploratory drilling.

Prior to the current study, a total of eight (8) long-term bedrock monitoring wells had been installed at the SQN site. Figure 3.10 indicates the depth of open borehole and/or screened interval for each well and wells are located as shown in Figure 1.2. Well construction details are provided in Appendix A.



Well	Bottom (ft-msl)	Open Borehole (ft)	Slotted Screen (ft)	Blank Casing (ft)
W1	553.9	86.5	None	65.2
W2	543.1	86.5	None	70.5
W4	611.9	5.4	None	115.0
W5	544.1	107.0	None	45.0
L6	654.9	9.4	45.1	69.5
L7	655.1	10.0	44.9	31.0
W8	444.1	210.0	None	40.0

Figure 3.10 Site Bedrock Monitoring Wells

Long-term groundwater level data have been collected to establish temporal trends for six wells at the SQN site. Since these monitoring wells are developed in bedrock and weathered bedrock, any deductions regarding groundwater movement is restricted to this flow regime. Figure 3.11 shows water level data obtained for wells W1, W2, L6, and L7. The plot indicates that groundwater levels measured for wells W1 and L6 are strongly influenced by reservoir stage. The fluctuation in groundwater levels at well L6 is almost completely correlated with the cyclic operation of the reservoir. Well W1 exhibits water levels that also correspond with the periodicity of reservoir stage; however, reservoir effects are diminished for times around 1986 and 1988. This might be attributed to drought conditions and diminished precipitation at the site during these times. The hydrographs for wells W2 and L7 appear to be influenced by water retention basins on the south side of the plant and do not display reservoir stage effects. Well W2 is located near the Yard Drainage Pond and well L7 is in the vicinity of the Return Channel. There is a large degree of correlation between water levels in the two wells and this may be related to plant discharges and pond operations. The free water surface in the Return Channel is maintained at a higher elevation than the reservoir by a discharge flume and weir. The minimum normal water surface elevation in the Return Channel is given as 689 ft-msl according to TVA drawing number 31W600-2. The average horizontal hydraulic gradient from well L7 to L6 is 0.01 ft/ft. The average horizontal hydraulic gradient from well W1 to W2 is about 0.003 ft/ft.

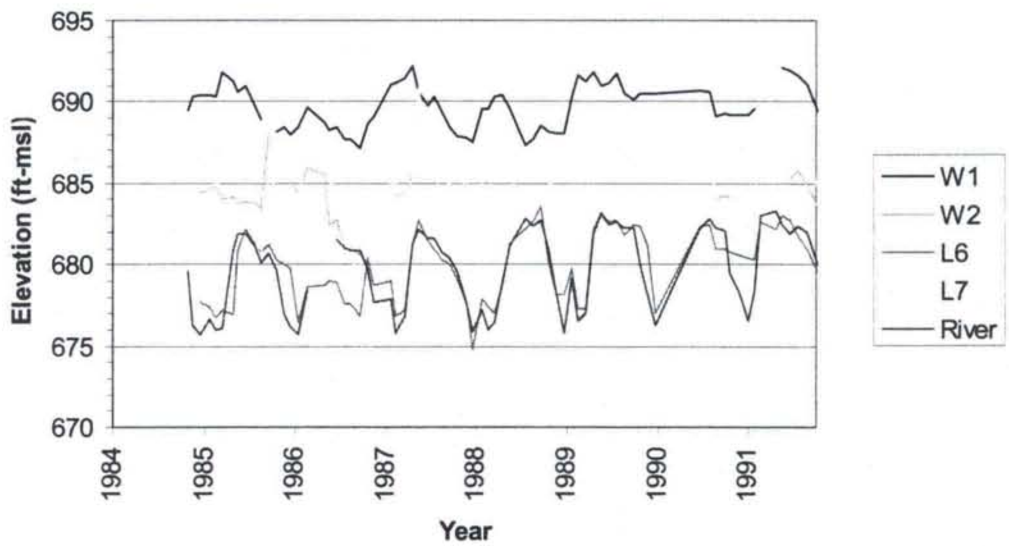


Figure 3.11 Time-Series Groundwater Levels for Wells W1, W2, L6, and L7 (1985-1991)

Figure 3.12 shows groundwater elevations for wells W1, W4, W5 and L7. This plot also indicates that the Return Channel and the Discharge Channel influence groundwater elevations in the southeastern area of the SQN site. The average horizontal hydraulic gradient from well W4 to L7 is approximately 0.0071 ft/ft; from well W1 toward the Intake Channel it is about 0.007 ft/ft; and from well W4 to W5 it is approximately 0.004 ft/ft.

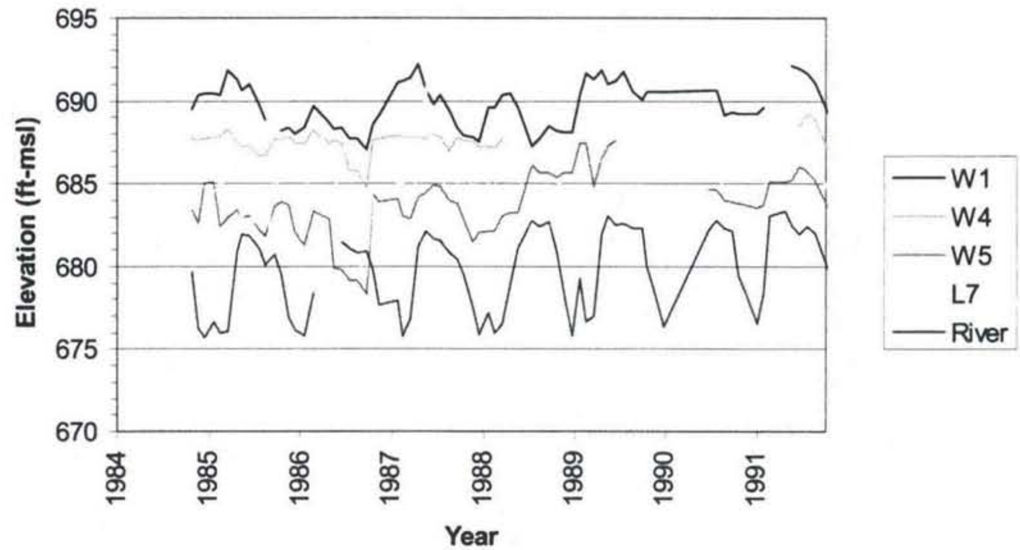


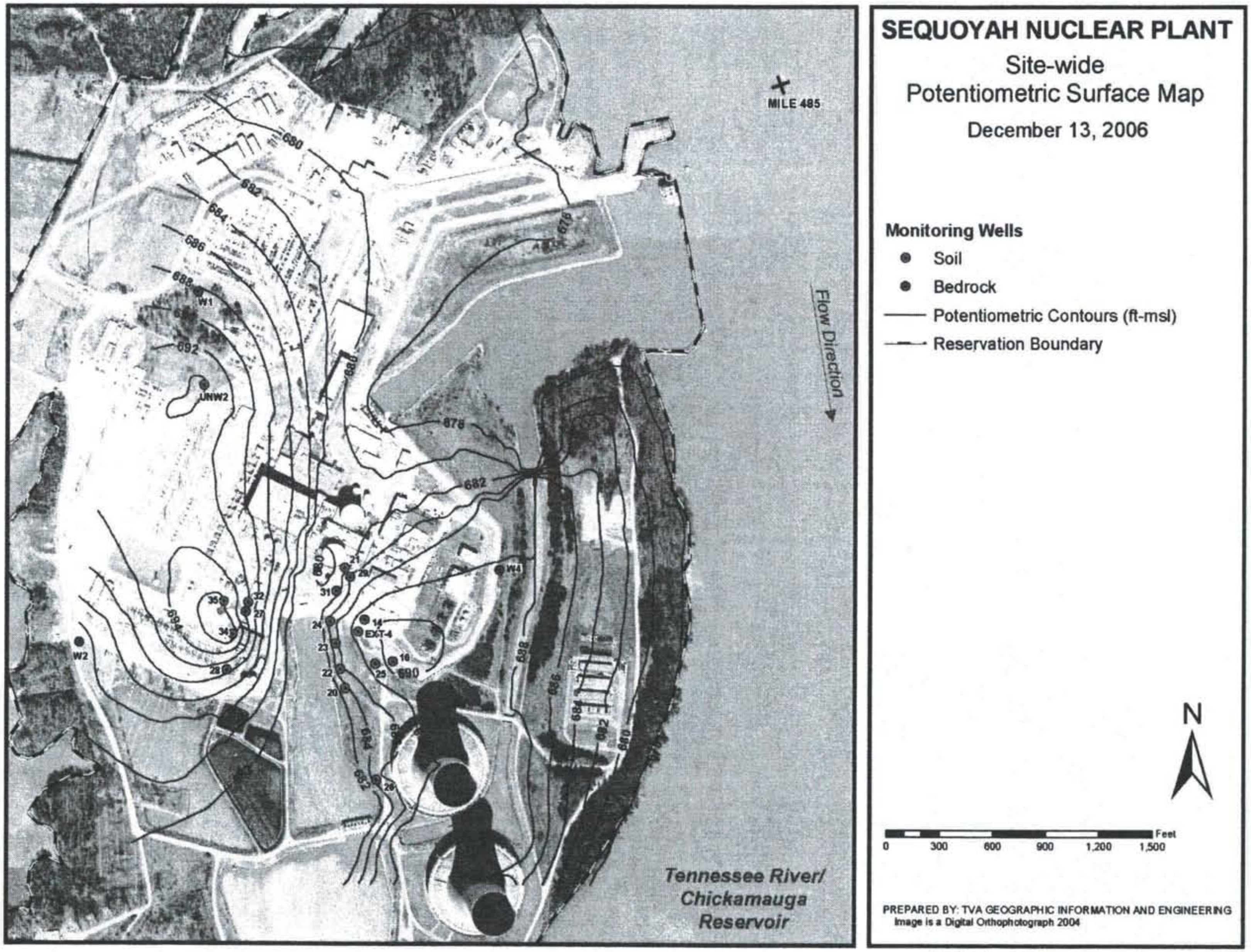
Figure 3.12 Time-Series Groundwater Levels for Wells W1, W4, W5 and L7 (1985-1991)

The direction of regional groundwater movement is primarily towards the SQN Intake and Discharge Channels based on historical and recent (12/13/2006) potentiometric mapping (Figure 3.13). Exceptions to this directional flux have occurred locally due to leaking water lines serving the site; in areas of topographic highs/lows; and from dewatering operations of the Diesel Fuel Oil Interceptor Trench.

Extensive pre-construction characterization studies were conducted at the plant site to determine the static physical characteristics of the soils. However, few field tests or laboratory measurements were performed to assess the hydraulic properties of site soils and bedrock. Laboratory permeameter testing of an undisturbed residual soil sample (boring US-53; TVA, 1979) indicates horizontal and vertical hydraulic conductivity values of 7.8E-07 and 1.3E-08 cm/s (a ratio of 1:60). A statistical summary of soil hydraulic properties at the LLRWSF (Table 3.1) suggests that residual soils and alluvium might be expected to exhibit saturated K values ranging from 5.8E-06 to 3.4E-09 cm/s.

Table 3.1 Statistical Summary of Soil Properties (from TVA, 1981)

Parameter	Minimum	Mean	Maximum	Standard Deviation	No. of Samples
Porosity	0.31	0.53	0.70	0.10	257
Density (lb/ft^3)	51.3	81.1	116.8	16.5	263
Saturated Hydraulic Conductivity (cm/s)	3.4E-09	7.9E-07	5.8E-06	1.8E-06	19
Natural Saturation (%)	41.0	93.0	100.0	9.0	263



SQN_Potentiometric_Surface_sitewide_map10.mxd - April 17, 2007

Figure 3.13 Site-Wide Potentiometric Map

Sorptive characteristics of soils beneath the LLRWSF have been determined through laboratory testing of soil samples (Rogers, 1982). Batch techniques were used on composite samples to measure distribution coefficients (K_d) for radionuclides identified in Table 3.2. The sorptive capacity of the Conasauga was not measured at the time due to the lack of a recognized procedure for obtaining realistic K_d values for rock cores. Table 3.2 summarizes laboratory K_d results for LLRWSF soils.

Table 3.2 Soil Distribution Coefficients (K_d)

Radionuclide	Kd (mL/g)		
	Minimum	Mean	Maximum
Co-58/60	1,740	4,820	8,000
Cs-134/137	850	2,390	>10,000
Sr-90	26	36	43
Mn-54	1,000	1,589	2,200
Zn-65	10,400	>10,400	>10,400

During investigations of the diesel fuel oil release, laboratory permeameter testing of undisturbed soil samples at well W14 (Edwards et al., 1993) provided vertical hydraulic conductivity values of 3.9E-07 and 1.6E-04 cm/s at depths of 8-10 and 23-25 ft, respectively. Both samples were characterized as clayey sands. The disparity in these hydraulic conductivity values prompted aquifer testing at the site by Julian (1993) to support final characterization and design of the Diesel Fuel Oil Interceptor System (Figures 3.14 and 3.15).

Single-well pump tests and Electromagnetic Borehole Flowmeter surveys (Young et al., 1997) were conducted by Julian (1993) at wells 22, 23, and EXT-4. The vertical distribution of horizontal hydraulic conductivity at each well is provided in Table 3.3. Incremental horizontal hydraulic conductivity ranged from 6.2E-07 to 1.9E-04 cm/s among all test wells.

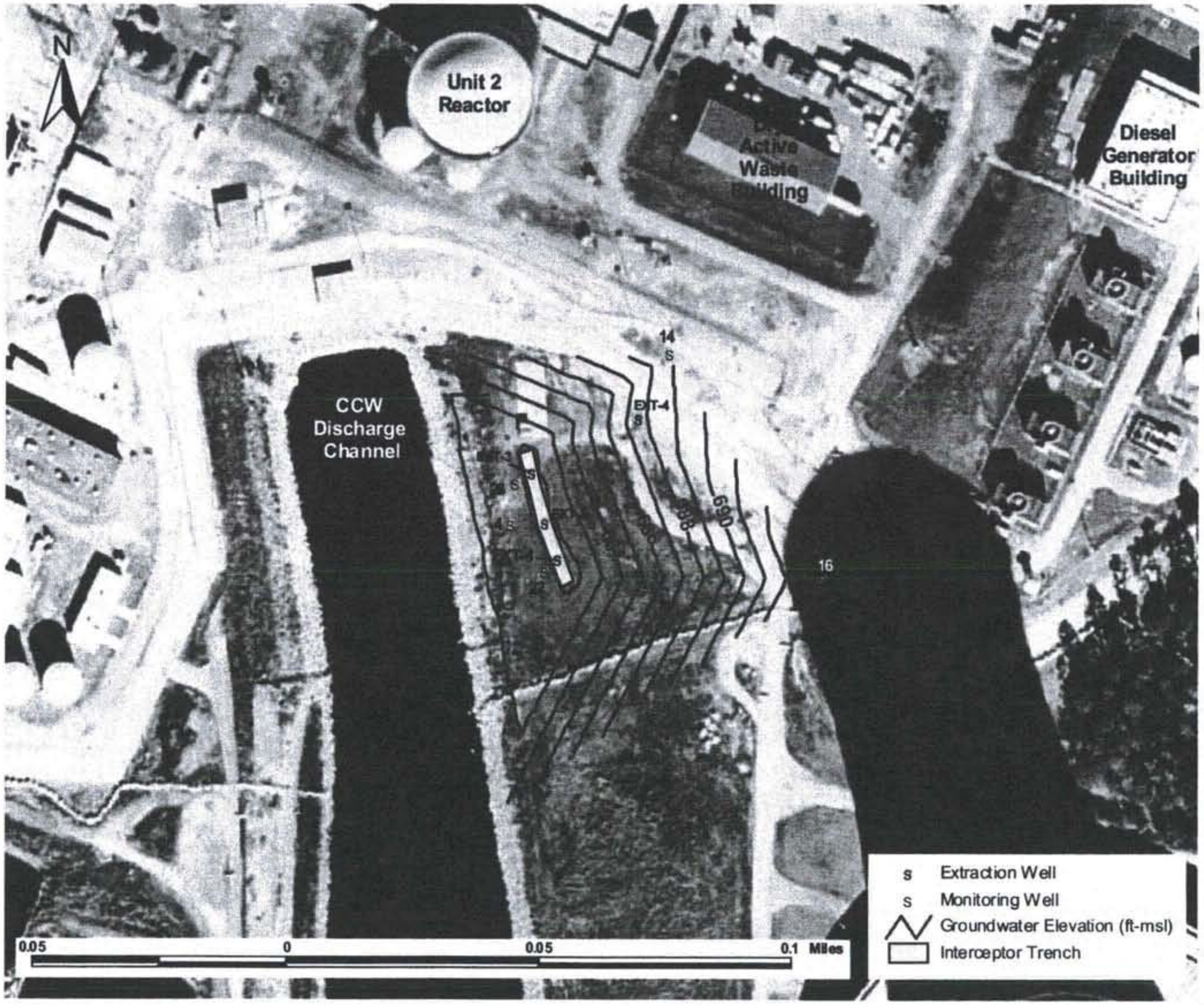
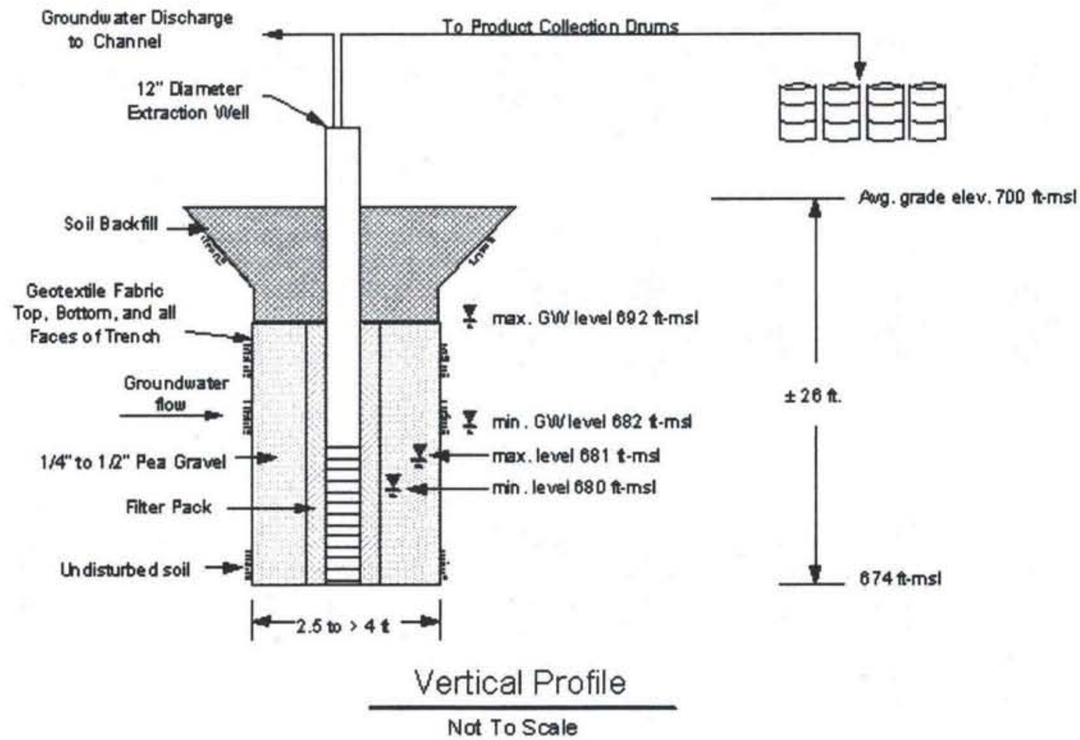


Figure 3.14 Potentiometric Surface at Diesel Fuel Oil Interceptor System on February 10, 2003



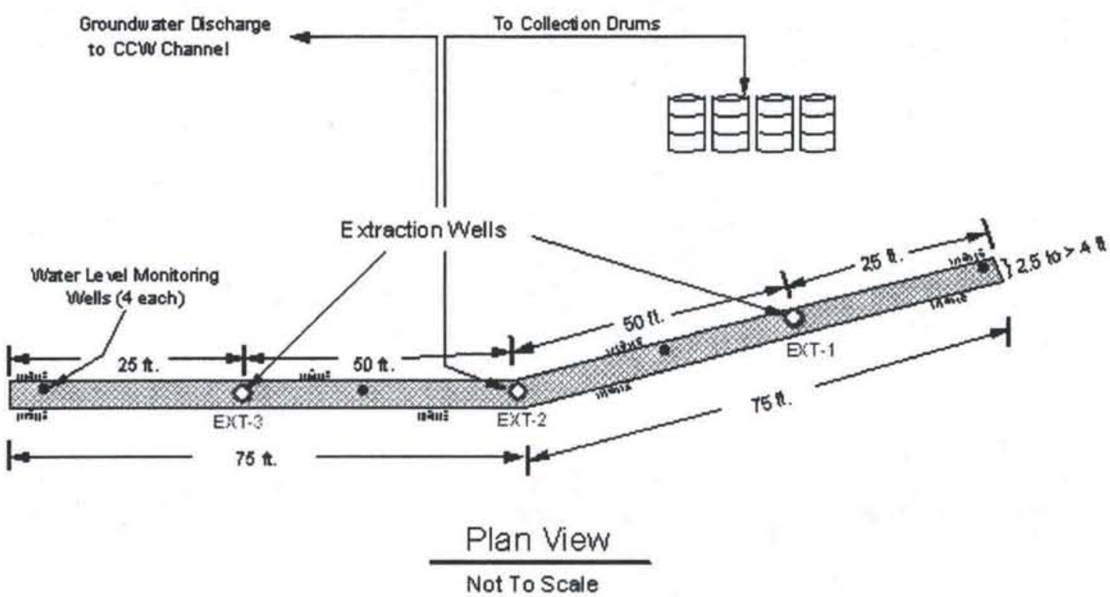


Figure 3.15 Schematic of Diesel Fuel Oil Interceptor Trench

Table 3.3 Horizontal Hydraulic Conductivity Values from Single-Well Testing at Wells 22, 23, and EXT-4

Elevation (ft-msl)	Horizontal Hydraulic Conductivity (cm/s)		
	Well 22	Well 23	Well EXT-4
676.4	5.4E-05		
676.7	1.2E-04		
677.7	1.8E-05		1.2E-04
678.7	4.6E-05		8.5E-05
679.7	3.7E-05		6.7E-05
680.7	4.0E-05	2.3E-05	1.4E-04
681.7	2.8E-05	1.5E-04	1.8E-05
682.7	3.0E-05	1.9E-04	8.2E-06
683.7	3.8E-05	1.4E-04	1.3E-04
684.7	7.3E-06	1.1E-04	6.7E-05
685.7	1.1E-05	5.1E-05	1.8E-04
686.7	8.1E-07	2.6E-05	1.9E-05
687.7	4.8E-06	1.7E-05	1.2E-05
688.7	3.2E-06	9.9E-06	1.1E-05
689.7	8.9E-06	1.7E-05	1.4E-06
690.7	3.2E-06	1.1E-06	6.8E-06
691.7	4.8E-06		1.2E-06
692.7	6.2E-07		
average =	2.5E-05	6.6E-05	5.7E-05

3.7 Offsite Water Supplies

3.7.1 Offsite Groundwater Supplies

When SQN was initially evaluated in the early 1970s, it was in a rural area, and only a few houses within a two-mile radius of the plant site were supplied by individual wells in the Knox Dolomite (TVA, 1979). Because the average domestic use probably did not exceed 500 gallons per day per house, groundwater withdrawal within a two-mile radius of the plant site was less than 50,000 gallons per day. Such a small volume withdrawal over the area would have essentially no effect on area groundwater levels and gradients. Although development of the area has increased, public supplies are available and overall groundwater use is not expected to increase.

TVA (2005) provide tabulated data of wells and springs located within a 20-mile radius of the site from 1985 surveys. Julian (2000) provides results from a United State Geological Survey (USGS) Ground-Water Site Inventory (GWSI) database retrieval for wells in Hamilton County. The data are a combination of domestic wells, wells installed for specific investigations, and other groundwater sites. Table 3.4 provides the results of this retrieval from the GWSI for

Hamilton County in the vicinity of SQN. Large capacity (i.e., discharge >100 gpm) well locations from the GWSI database are depicted in Figure 3.16.

Table 3.4 Wells in the Vicinity of SQN from GWSI Database

Well Number	Latitude	Longitude	Depth (ft)	Discharge (gpm)	Aquifer
Hm:N-090	351147	851308	67	5,400	
Hm:N-089 HIXSON NO.3 PUMP	351148	851353	177	4,000	Newman Limestone
Hm:0-018	350750	850458	148	2,000	Chepultepec Limestone
Hm:O-030 SAVANNAH VALLEY	351114	850252	145	1,500	
Hm:O-016	351424	850039	158	900	
Hm:O-015	351428	850036	262	800	Knox Group
Hm:O-008	351428	850039	120	760	
Hm:J-016 EASTSIDE	350719	850509		400	Knox Group
Hm:O-031	351115	850250	150	350	
Hm:N-048 BINKLEY, S.DENT	351041	851237	180	300	
Hm:N-056 THRASHER RR	351239	851250	103	300	Paleozoic
Hm:N-075 FREEMAN WELL	351158	851117	202	270	
Hm:N-083 USGS-TDOT	351150	851405	202	260	
Hm:J-015 EASTSIDE +DUP	350720	850510	182	250	Knox Group
Hm:O-003	351054	850238	250	250	
Hm:N-060 OLDAKER 14	351228	851010	144	250	Paleozoic
Hm:N-059 WALKER 14A	351249	851101	223	245	Paleozoic
Hm:N-086 USGS-REEVE	351407	851147	202	240	
Hm:R-015	352038	850813	390	200	
Hm:O-007	351437	850027	247	170	
Hm:R-005 UNION-FORK/BAKE	352031	850819	193	160	
Hm:R-073 NORRIS WELL	351525	850853	190	150	
Hm:O-017 EASTSIDE	350735	850530	280	105	Knox Group
Hm:J-013 EASTSIDE	350607	850510	251	100	Knox Group
Hm:J-014 EASTSIDE	350655	850520	250	100	Knox Group
Hm:N-084 USGS-CONARD	351320	851320	202	100	
Hm:R-004	352031	850816	330	70	
BOWMAN WELL AT SALE CR	352532	850848	1,310	40	
Hm:O-041	351206	850307	112	20	
Hm:S-008	351522	850417	75	20	
Hm:N-054 FLOYD THRASHER	351223	851252	279	19	
Hm:S-007	351943	850049	60	16	
Hm:J-001	350614	850047	80	15	
Hm:N-002	350953	850843	100	15	
Hm:J-002	350504	850246	160	10	
Hm:N-046 HUD QUARRY	350937	851314	242	7	Paleozoic
Hm:N-078 NOE	351320	850740	280	7	
Hm:O-074 VINCENT WELL	351432	850637	342	7	
Hm:S-006	351549	850516	269	5	
Hm:N-049 RAGAN HUD	351137	851341	270	2	

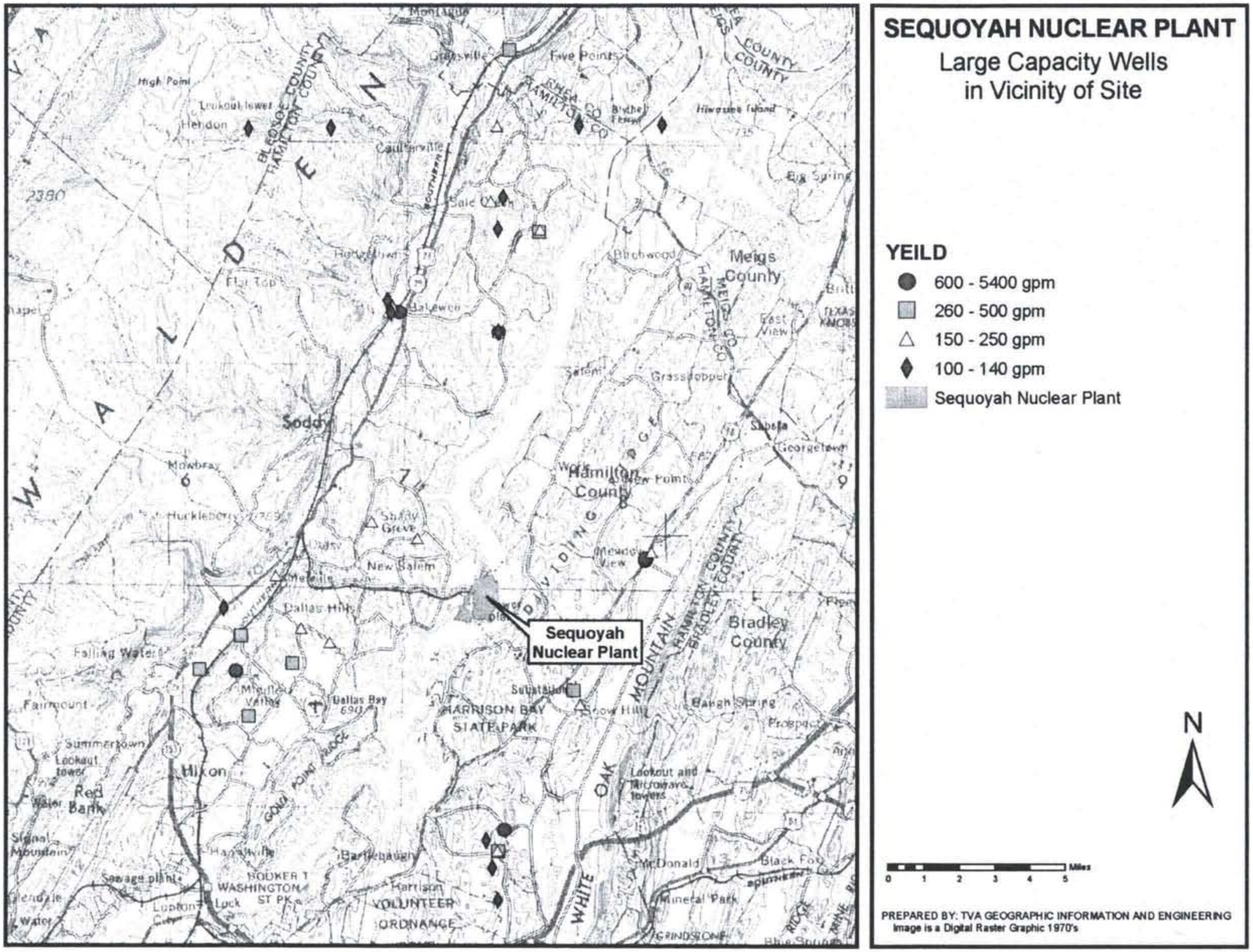


Figure 3.16 Large Capacity Wells in the Vicinity of SQN from USGS GWIS Database

Bradfield (1992) conducted a study of Cave Springs from 1987 to 989. This the second largest spring in East Tennessee and an important water supply. Cave spring is located approximately 8 miles southwest of SQN near state Highway 27. In addition to wells in the immediate vicinity of Cave Spring, Bradfield (1992) examined water groundwater quality/quantity for water supply wells in the region. Table 3.5 lists attributes of wells included in the study and Figure 3.17 shows the well locations relative to SQN.

Table 3.5 Wells in the Vicinity of SQN from Bradfield (1992)

Well Number	Ground Elevation (ft-msl)	Well Depth (ft)	Casing Depth (ft)	Soil Thickness (ft)	Estimated yield (gpm)	Depth Water-Bearing Zone(s) (ft)
1	710	71	61	25	3,000	65-70
2	710	73	63	25	3,000	65-70
3	710	398	82	25	>300	160, 190 260, 275, 320
4	710	177	140	25	>4,000	167-173
6	661	322	148	127	300	180, 270
7	820	298	296	298	15	160-180, 270-290
8	880	231	226	231	5	200-231
9	685	103	93	37	400	59-71, 75-93, 98-103
11	786	223	180	179	400	201-220
12	723	142	95	95	200	95-131
13	730	242	147	50	100	50-70, 177
14	850	302	130	124	<1	150-200
15	827	202	194	202	30	143-147, 197-202
16	770	251	135	126	40	200-250
17	750	190	188	174	200	175-90
18	703	342	88	85	100	299, 327
19	729	202	154	150	200	170-200
20	692	101	62	37	50	70-90
21	780	171	165	165	50	165-171
22	707	280	84	69	50	78
23	720	342	117	93	200	85-93

The majority of these wells are included in the GWSI database retrieval (Table 3.4). The relatively high well yields shown in Table 2 and Figure 3 (i.e. wells 1-6) are associated with the Cave Springs water supply. Other wells distributed across the region northeast of Cave Springs (Figure 3.17) are affiliated with productive carbonate aquifers.

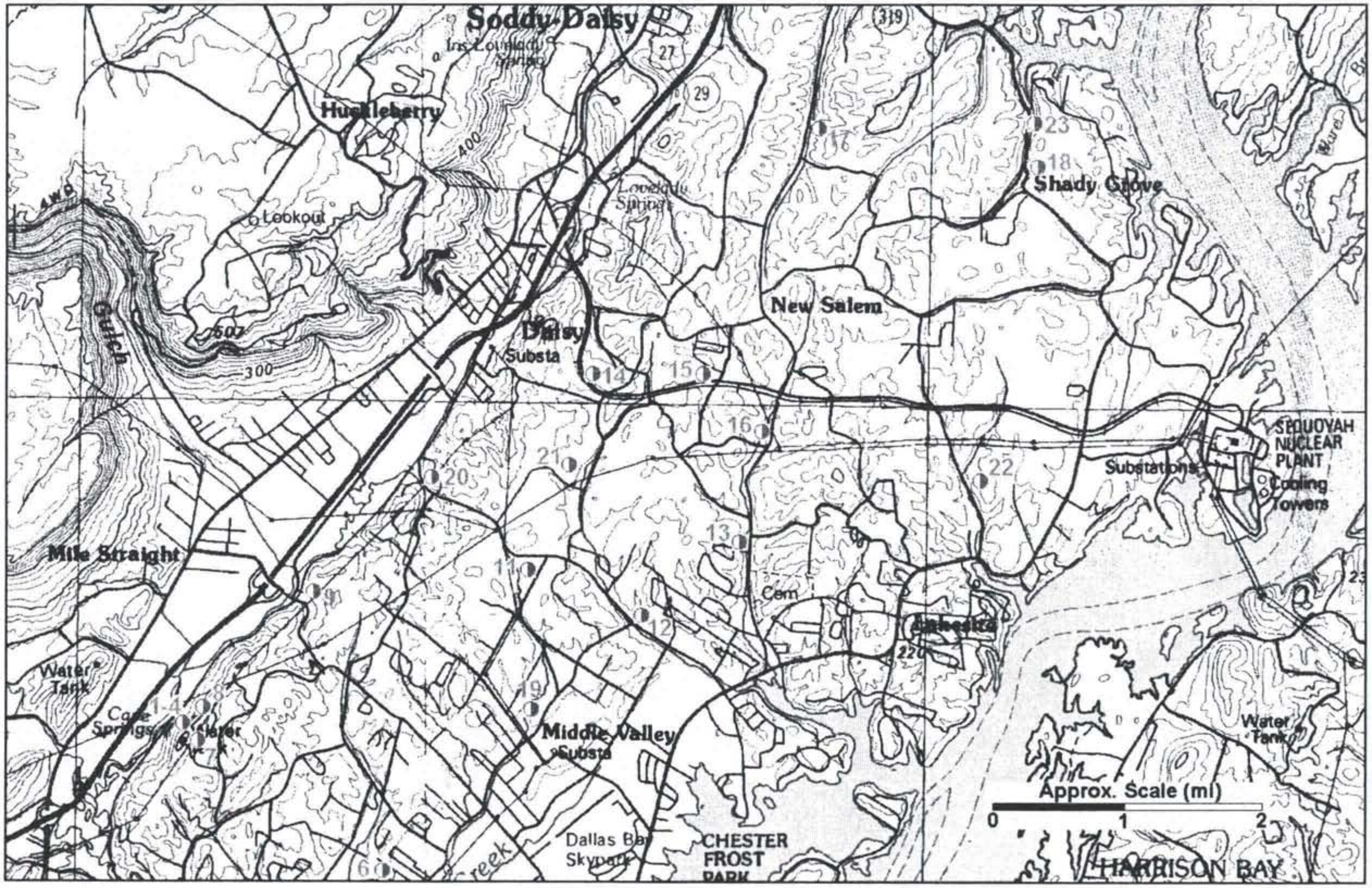


Figure 3.17 Groundwater Supply Wells in the Vicinity of SQN from Bradfield (1992)

3.7.2 Offsite Surface Water Supplies

As listed in Table 3.6, there are 23 surface water users within the 98.6-mile reach of the Tennessee River between Dayton, Tennessee and Stevenson, Alabama. These include fifteen industrial water supplies and eight public water supplies (TVA, 200*).

The public surface water supply intake (Savannah Valley Utility District), originally located across Chickamauga Reservoir from the plant site at TRM 483.6, has been removed. Savannah Valley Utility District has been converted to a ground water supply. The nearest public downstream intake is the East Side Utility (formerly referred to as U.S. Army, Volunteer Army Ammunition Plant). This intake is located at TRM 473.0.

Table 3.6 Public and Industrial Surface Water Supplies Withdrawn from 98.6 Mile Reach Of Tennessee River Between Dayton, TN and Stevenson, AL

Intake Name	Use (MGD)	Location	Approximate Distance from Site (River Miles)	Type Supply
City of Dayton	1.78	TRM 503.8 R	19.1 (Upstream)	Municipal
Cleveland Utilities Board	5.03	TRM 499.4 L Hiwassee RM 22.9	37.6 (Upstream)	Municipal
Bowaters Southern Paper	80.00	TRM 499.4 L Hiwassee RM 22.7	37.4 (Upstream)	Industrial & Potable
Hiwassee Utilities	3.00	TRM 499.4 L Hiwassee RM 22.5	37.2 (Upstream)	Municipal
Olin Corporation	5.00	TRM 499.4 L Hiwassee RM 22.3	37.0 (Upstream)	Industrial & Potable
Soddy-Daisy Falling Water U.D.	0.93	TRM 487.2 R Soddy Cr. 4.6 Plus 2 Wells	7.1 (Upstream)	Municipal
Sequoyah Nuclear Plant	1615.70	TRM 484.7 R	0.0	Industrial
East Side Utility	5.00	TRM 473.0 L	11.7 (Downstream)	Municipal
Chickamauga Dam	not measured	TRM 471.0	13.7 (Downstream)	Industrial
DuPont Company	7.20	TRM 469.9 R	14.8 (Downstream)	Industrial
Tennessee-American Water	40.90	TRM 465.3 L	19.4 (Downstream)	Municipal
Rock-Tennessee Mill	0.50	TRM 463.5 R	21.2 (Downstream)	Industrial
Dixie Sand and Gravel	0.04	TRM 463.2 R	21.5 (Downstream)	Industrial
Chattanooga Missouri Portland Cement	0.10	TRM 456.1 R	28.6 (Downstream)	Industrial
Signal Mountain Cement	2.80	TRM 454.2 R	30.5 (Downstream)	Industrial
Raccoon Mount. Pump Storage Project	0.56	TRM 444.7 L	40.0 (Downstream)	Industrial
Signal Mountain Cement	0.20	TRM 433.3 R	51.4 (Downstream)	Industrial
Nickajack Dam	not measured	TRM 424.7	60.0 (Downstream)	Industrial
South Pittsburg	0.90	TRM 418.0 R	66.7 (Downstream)	Municipal
Penn Dixie Cement	0.00001	TRM 417.1 R	67.6 (Downstream)	Industrial
Bridgeport	0.60	TRM 413.6 R	71.1 (Downstream)	Municipal
Widows Creek Stream Plant	397.40	TRM 407.7 R	77.0 (Downstream)	Industrial
Mead Corporation	4.40	TRM 405.2 R	79.5 (Downstream)	Industrial

R = Right River Bank, L = left River Bank

4.0 TRITIUM INVESTIGATION

Field investigations during this study focused largely on areas north and south of Units 1 and 2. Initial identification of areas for targeted investigations was based on information collected from the following sources:

- Preliminary site meetings with SQN staff;
- Previous tritium monitoring results associated with wells located along waste condensate lines;
- Historical tritium detection at other monitoring wells (e.g., W5 and W21);
- Preliminary assessments of inadvertent liquid radwaste releases;
- Relative locations of large/deep underground appurtenances;
- Potentially transmissive groundwater migration routes (e.g., pipeline bedding pathways).

The majority of tritium data collected from site groundwater monitoring prior to initiation of this investigation was available for review in spreadsheet format. Temporal and spatial examination of groundwater tritium concentrations data was conducted prior to field investigations. Reports documenting inadvertent liquid radwaste releases were made available by SQN staff. Hardcopy and electronic versions of essential site drawings were examined prior to and during field investigations. Key site features (e.g., underground lines and conduits) were electronically digitized and georeferenced imagery was developed using Geographic Information System (GIS) methods. Spatial data were incorporated into the GIS geodatabase with project progression. Several thousand large format (8 x 10 inch) photograph negatives (prepared during plant construction) were also examined at the National Archives Southeast Region Facility.

Preliminary results suggested that tritium sources might be associated with inadvertent liquid releases from the MFTDS, Unit 1 and 2 RWST, CDWE Building, and/or the Unit 2 Additional Equipment Building. Based on comparable tritium investigations completed at WBN (ARCADIS, 2004), and similarity of SQN plant design to WBN, the Unit 1 and 2 Auxiliary and Shield Buildings were included as potential tritium sources during this investigation. Major tasks associated with the field investigation included:

1. Sampling of selected existing wells;
2. Manual sampling of storm drain catch basins, vaults, and manholes;
3. Groundwater sampling using Geoprobe methods;
4. Manual and continuous water level monitoring;
5. Interior sampling at select locations.

4.1 Groundwater Sampling of Selected Existing Wells

Initial groundwater sampling for this study was targeted at site perimeter wells to confirm that offsite migration of tritium is not occurring. Fourteen existing wells were selected for sampling (Table 4.1). These wells are located along site boundaries and are not presently included in the routine groundwater monitoring network for tritium. Well locations are shown in Figure 1.2. This sampling event included three bedrock wells (W1, W2, W4), soil/bedrock well L6 at the LLRWSF, eight soil wells south of Unit 2 (14, 16, 20, 22, 30, 32, 34, 35), and two diesel extraction wells (EXT-2, EXT-4) located near the discharge.

Table 4.1 Tritium Results from Selected Existing Wells

Location	Diameter (in)	Top of Casing (ft-msl)	Top of Ground (ft-msl)	Depth from TOC (ft)	Bottom of Hole (ft-msl)	Sampling Date	Tritium Concentratio n (pCi/L)
W1	6	708.9	705.6	155.0	553.9	10/04/2006	< 270
W2	6	700.9	700.1	157.8	543.1	10/05/2006	< 270
W4	6	742.3	732.3	130.4	611.9	10/05/2006	< 270
L6	3	734.8	733.8	79.7	655.1	10/04/2006	< 270
14	2	707.9	705.2	18.8	689.1	10/06/2006	< 270
16	2	707.6	706.1	23.6	684.0	10/06/2006	< 270
20	2	697.9	697.9	23.1	674.8	10/05/2006	< 270
22	2	700.9	698.4	21.4	679.5	10/05/2006	< 270
30	1	707.2	704.1	23.8	683.4	10/06/2006	< 270
32	1	706.3	704.1	22.7	683.7	10/06/2006	< 270
34	1	708.1	704.8	25.7	682.5	10/06/2006	< 270
35	1	708.9	705.8	23.6	685.3	10/06/2006	< 270
EXT-2	12	702.2	700.0	26.0	676.2	10/06/2006	< 270
EXT-4	12	704.4	700.0	26.0	678.4	10/06/2006	< 270

Wells were purged and sampled October 4-6, 2006, using a combination of submersible pumps and disposable Teflon bailers. Samples were collected in 100 mL wide-mouth plastic sample containers and transferred to plant personnel for shipment to WARL for tritium analysis. Laboratory analysis indicated that tritium concentrations were less than the MDC of 270 pCi/L at all locations.

Perimeter well W5 has historically exhibited the presence of tritium but was not included in this sampling scheme since it is routinely monitored by SQN and WARL personnel through REMP.

4.2 Manual Sampling of Storm Drain Catch Basin, Vaults, and Manholes

Storm drain catch basins, vaults, and manholes were sampled to detect potential in-leakage of tritiated water from groundwater or discharge from plant processes. Sampling locations were initially identified using the following criteria: availability of water, depth (i.e., deep storm drain catch basins), accessibility, and proximity to the waste condensate lines and historical releases.

Twenty sites were selected (Table 4.2), including eighteen catch basins, the Turbine Building Sump Discharge, and a TV box sump. Sample locations are shown in Figure 4.1. All locations selected for sampling were within several hundred feet of the Reactor Buildings.

Table 4.2 Tritium Results from Manual Sampling Event

Location	Type	Depth to Invert (ft)	Depth to Water (ft)	Sampling Date	Tritium Concentration (pCi/L)
SS-1	Catch Basin	4.96	4.69	10/13/2006	< 270
SS-2	Catch Basin	5.10	5.03	10/13/2006	< 270
SS-3	Catch Basin	2.70	2.59	10/13/2006	< 270
SS-4	Catch Basin	5.10	5.00	10/13/2006	< 270
SS-5	Catch Basin	3.77	3.74	10/13/2006	< 270
SS-6	Catch Basin	2.61	2.61	10/13/2006	8,879
SS-7	Catch Basin	4.29	3.99	10/13/2006	< 270
SS-9	Catch Basin	5.03	4.99	10/13/2006	< 270
SS-10	Catch Basin	6.37	6.10	10/13/2006	< 270
SS-11	Catch Basin	8.31	8.07	10/13/2006	< 270
SS-12	Catch Basin	8.06	7.52	10/13/2006	< 270
SS-13	Catch Basin	2.05	2.04	10/13/2006	< 270
SS-14	Catch Basin	1.93	1.82	10/13/2006	425
SS-15	Turbine Building Sump	N/A		10/13/2006	< 270
SS-16	Catch Basin	3.46	3.39	10/13/2006	< 270
SS-17	Catch Basin	12.59	12.40	10/13/2006	< 270
SS-18	Catch Basin	10.18	9.84	10/13/2006	< 270
SS-19	Catch Basin	3.70	3.61	10/13/2006	< 270
SS-21	TV Box Sump	2.56	1.78	10/13/2006	284
SS-22	Catch Basin	7.80	7.59	10/13/2006	312

Samples were collected October 13 by dropping a sponge (on a string) through the catch basin grating to soak up water, retrieving it, and then wringing it into a 100 mL wide-mouth plastic sample container. Sponge and string were disposed of after each location sampled. The outside of the sampling containers were thoroughly rinsed to remove any trace of overflow. Depth-to-water and depth-to-invert were measured after sampling using an electronic water level meter, and the water level meter was decontaminated between locations. Sample containers were transferred to SQN personnel, then transported to WARL for tritium analysis.

Table 4.2 summarizes sampling results. Tritium was observed at catch basin locations SS-6 (8,879 pCi/L), SS-14 (425 pCi/L), SS-21 (284 pCi/L), and SS-22 (312 pCi/L). All other samples were less than the MDC.

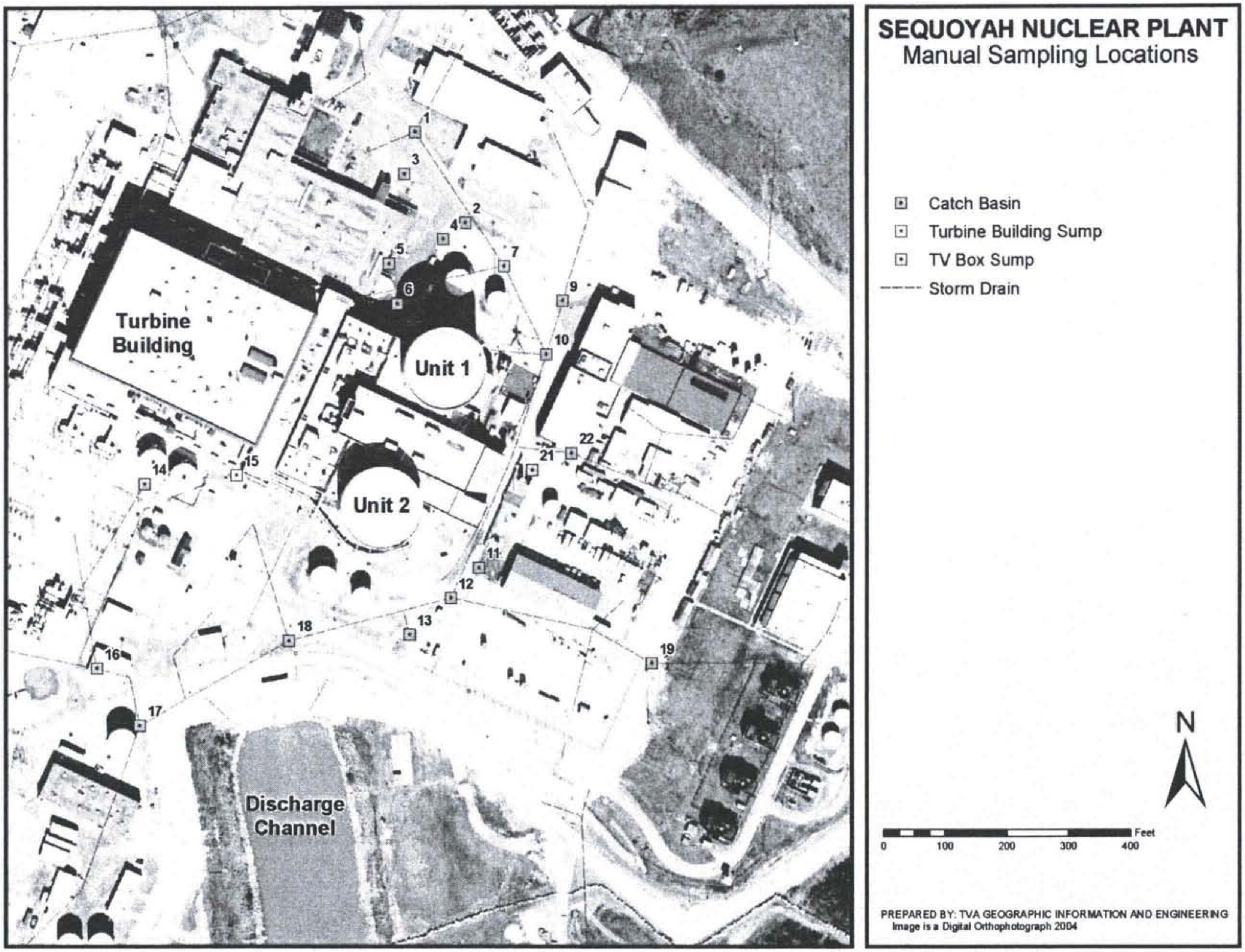


Figure 4.1 Map of Manual Sampling Locations

4.3 Groundwater Sampling using Geoprobe Methods

Groundwater sampling using a Geoprobe allows sampling rods to be "pushed" into the ground without the use of drilling and produces minimal investigation-derived waste. The Geoprobe direct-push machine relies on a relatively small amount of static (vehicle) weight combined with percussion as the energy for advancement of a tool string. The Geoprobe offers a significant safety advantage since the probe tends to resist on concrete and steel pipelines, and downholes tools are easily decontaminated between borings.

Thirty-one (31) Geoprobe boring locations were initially identified at the site based on the existing knowledge of groundwater movement and the relative locations of major underground lines and appurtenances (e.g., ERCW lines and intake conduits). Bedding materials surrounding underground lines represent potential preferential pathways for subsurface movement of groundwater contaminants; therefore, these features were a consideration of the investigation. Site design and as-built drawings of underground utilities were reviewed in relation to proposed boring locations to avoid potential drilling conflicts. For final verification of proposed boring locations, a radio frequency utility location investigation was conducted under contract with Underground Locators of Nashville, Inc, during November 2006. The utility location survey evaluated potential utilities and metallic obstructions around the areas of the field-staked boring locations. The boring locations were offset if direct obstructions were identified to provide a minimum horizontal clearance of the 2-ft locate variation in all directions.

Sampling of groundwater using Geoprobe methods was conducted during January and February 2007. Due to subsurface resistance at many locations (i.e., concrete), groundwater samples were ultimately collected at 23 locations (Figure 4.2; Table 4.3). When possible, groundwater samples were collected in situ (from within the Geoprobe push-rod at depth) using a 0.5-inch OD stainless steel bailer or were siphoned using Teflon tubing. Where groundwater recovery rates were slow, temporary 0.5-inch ID screen and casing were installed and samples were collected using a 0.5-inch OD stainless steel bailer or were siphoned using Teflon tubing. All temporary well materials were discarded after a single use; although, in some cases, Teflon tubing was reused after being decontaminated between samples. Groundwater samples were transferred to 100 mL wide-mouth plastic sample containers, and turned over to plant personnel to transmit to WARL for tritium analysis. Decontamination involved scrubbing downhole equipment with a distilled water/laboratory detergent mix and rinsing with distilled water.

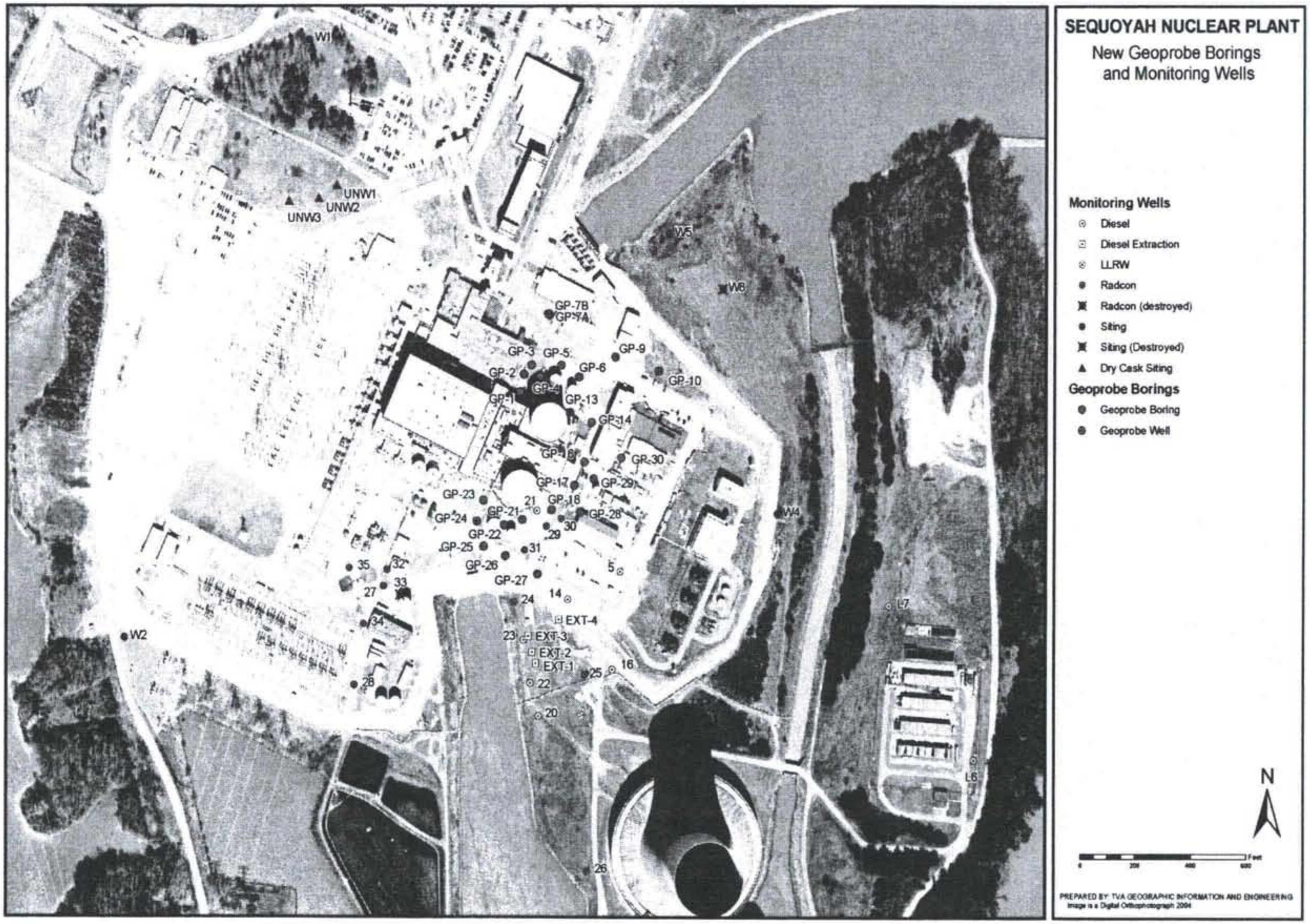


Figure 4.2 Map Showing Geoprobe Sampling Locations and Monitoring Wells

Figure 4.3 provides a profile of Geoprobe borings installed during the investigation. Five of the borings were completed as 1-inch monitoring wells to supplement groundwater level measurements in areas lacking groundwater level information. These wells include GP-7A, GP-7B, GP-10, GP-13, and GP-24 (Figure 4.2). Well diagrams are provided in Appendix A.

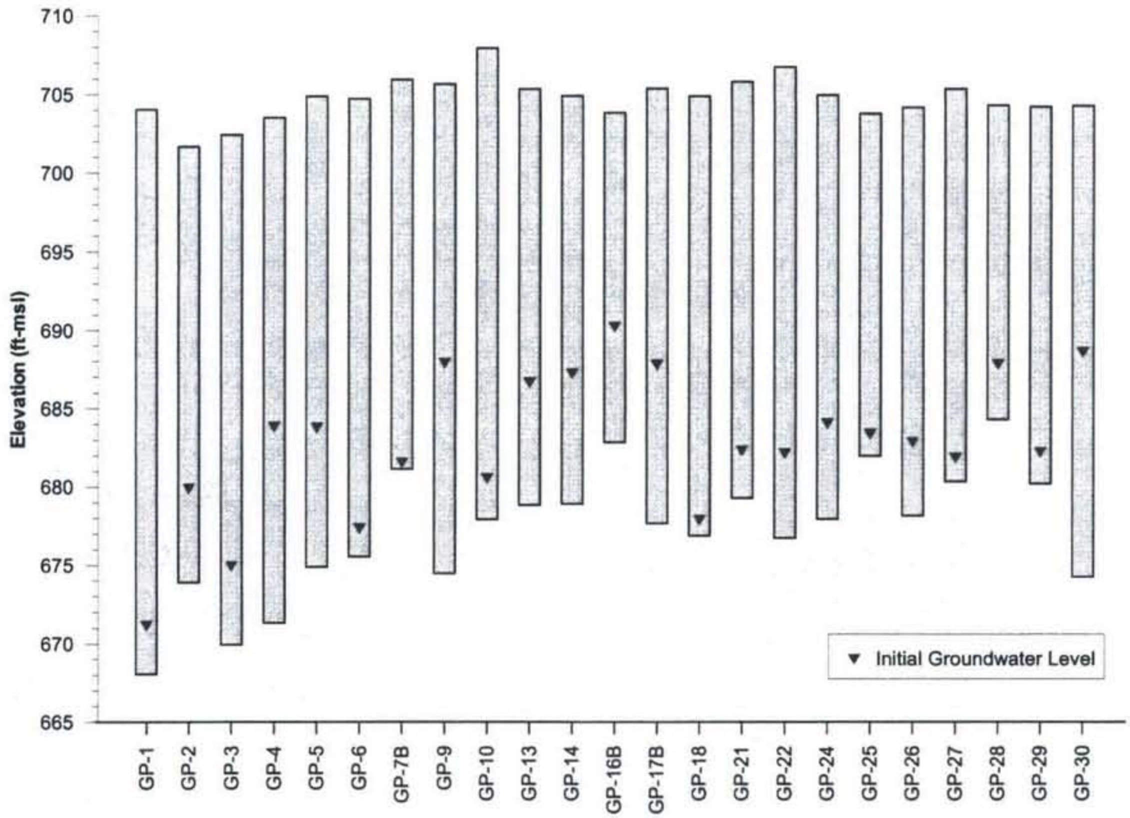


Figure 4.3 Profile of Geoprobe Borings

Table 4.3 provides a summary of groundwater sampling locations and analytical results from Geoprobe investigations. As indicated, tritium was observed at low concentrations in borings (GP-1 – GP-7) near the Unit 1 RWST, in borings S-SE of Unit 2 (GP-21, GP-22, GP-25, GP-26), and at GP-28. The highest tritium concentration observed in Geoprobe borings occurred at GP-13 (16, 211 pCi/L).

Table 4.3 Tritium Results from Geoprobe Sampling

Location	Top of Ground (ft-msl)	Depth (ft)	Bottom of Hole (ft-msl)	TN NAD27 (ft) Easting	Northing	Sampling Date	Tritium Concentration (pCi/L)
GP-1	704.1	36.0	668.1	2271360.0	305170.7	1/26/2007	274
GP-2	701.7	27.8	673.9	2271373.9	305226.7	1/29/2007	733
GP-3	702.4	32.5	669.9	2271401.2	305258.6	1/25/2007	623
GP-4	703.5	32.2	671.3	2271433.3	305221.2	1/30/2007	661
GP-5	704.9	30.0	674.9	2271510.6	305256.8	1/25/2007	420
GP-6	704.7	29.2	675.5	2271575.9	305218.7	1/25/2007	306
GP-7B	705.9	24.8	681.1	2271461.1	305425.8	2/12/2007	394
GP-9	705.7	31.2	674.5	2271708.1	305284.7	1/31/2007	< 270
GP-10	707.9	30.0	677.9	2271366.7	305237.9	2/01/2007	< 270
GP-13	705.3	26.5	678.8	2271543.4	305102.4	2/01/2007	16,211
GP-14	704.9	26.0	678.9	2271621.5	305069.1	2/05/2007	< 270
GP-16B	703.8	21.0	682.8	2271594.8	304938.8	2/15/2007	< 270
GP-17B	705.4	27.7	677.7	2271558.3	304862.1	2/16/2007	< 270
GP-18	704.9	28.0	676.9	2271476.6	304781.9	2/06/2007	< 270
GP-21	705.8	26.5	679.3	2271368.9	304750.0	2/06/2007	750
GP-22	706.7	30.0	676.7	2271304.2	304732.2	2/07/2007	2,700
GP-24	704.9	27.0	677.9	2271204.3	304744.0	2/07/2007	< 270
GP-25	703.8	21.8	682.0	2271230.4	304662.1	2/07/2007	874
GP-26	704.1	26.0	678.1	2271309.7	304630.9	2/07/2007	332
GP-27	705.3	25.0	680.3	2271425.5	304571.1	2/12/2007	< 270
GP-28	704.3	20.0	684.3	2271580.9	304774.2	2/13/2007	394
GP-29	704.2	24.0	680.2	2271629.2	304884.0	2/13/2007	< 270
GP-30	704.2	30.0	674.2	2271730.8	304953.5	2/13/2007	< 270

4.4 Water Level Monitoring

Groundwater level monitoring at the site during this investigation included manual measurements at existing wells and new wells in close proximity to the plant site on approximately a monthly basis beginning December 13, 2006. Continuous water level and temperature monitoring was conducted at three selected wells (14, W21, and GP-13) and at the head of the Discharge Channel. Solinst (Model 3001) downhole dataloggers were deployed (beginning 11/17/06) for continuous monitoring of water levels and temperatures. Continuous (hourly) surface water levels are collected for Chickamauga Reservoir on the southeast corner of the Intake Channel Skimmer Wall (Figure 1.1) at TRM 484.8.

Results from pre-investigation water level monitoring were coupled with recent data. Figure 4.4 depicts time-series groundwater levels for wells W21, 29, 30, and 31 in the vicinity of Unit 2. As shown in the figure, groundwater gradients are consistent with time and all groundwater levels are influenced by operation of the Chickamauga Reservoir and the Discharge Channel (see Section 3.3). That is, under normal operations, water elevation begins to increase in April and recession begins in September. The maximum range of groundwater levels over this 3-year interval is 9.7 ft (wells W21 and 31). Groundwater levels at wells 29 and 30 fluctuated over < 6.0 ft for this period. Apparent in Figure 4.4 is the excellent degree of correlation in groundwater levels at wells W21 and 31.

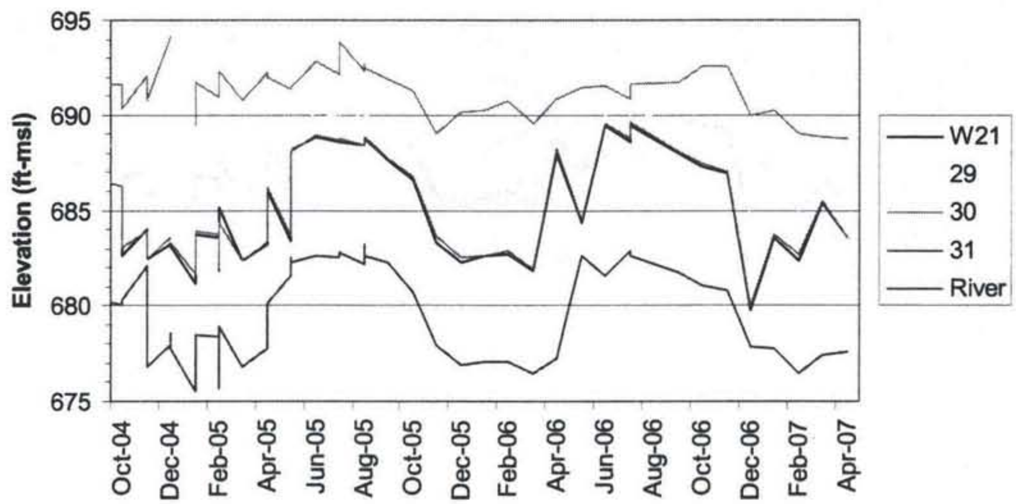


Figure 4.4 Time-Series Water Levels at Wells W-21, 29, 30, 31 and the River

Figure 4.5 shows time-series groundwater levels for RadCon wells in the vicinity of the 12-inch Waste Condensate Line. Although these wells are located at similar distances from the Discharge Channel, groundwater levels are not correlated with surface water elevations. However, correlation in groundwater levels among these wells is evident. Compared to wells nearer Unit 2, the maximum range of groundwater levels over this 3-year interval was 13.1 ft (well 34). Groundwater levels at wells 27 and 33 fluctuated over <5.0 ft for this period.

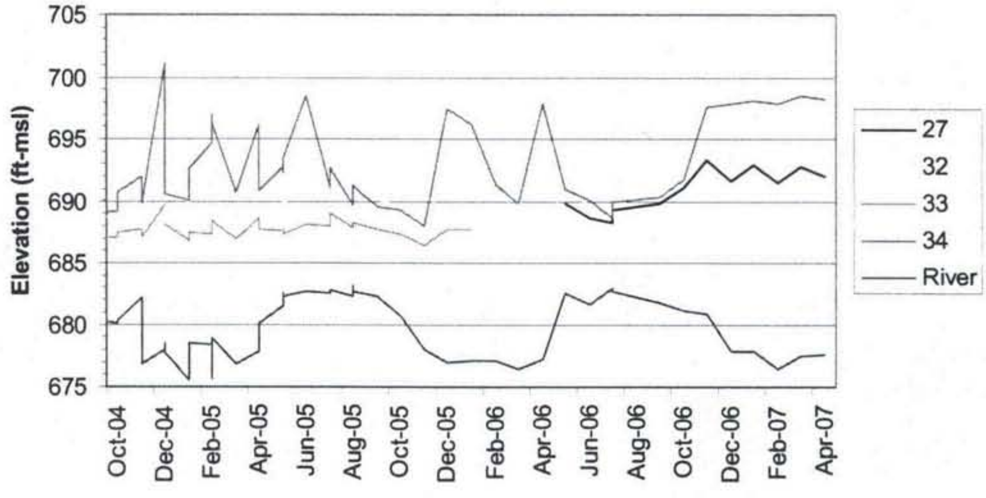
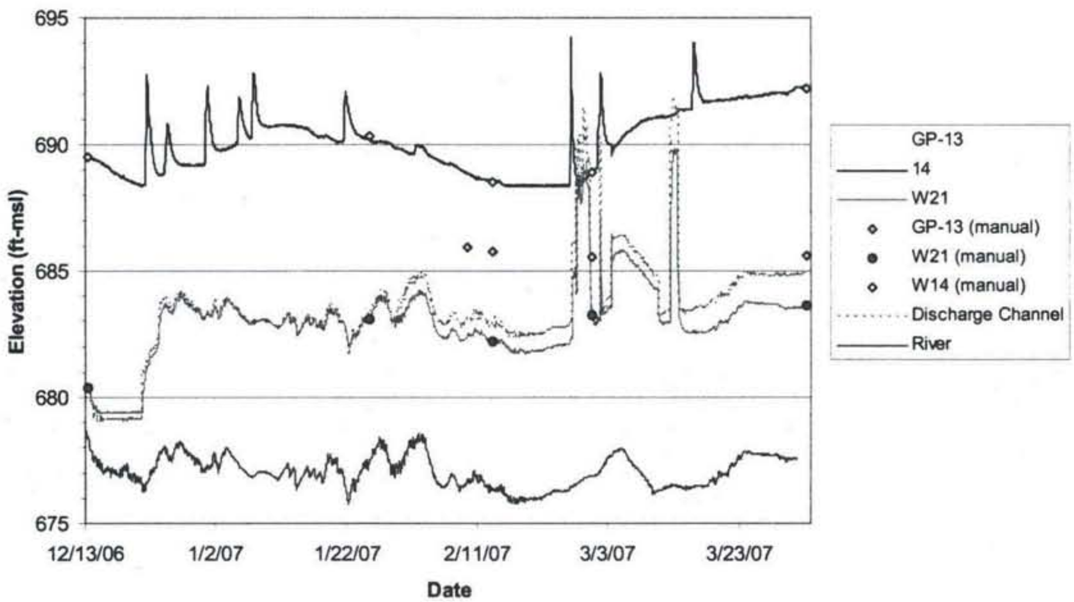


Figure 4.5 Time-Series Water Levels at Wells 27, 32, 33, 34 and the River

Continuous temperature and water level data collected for this investigation are presented in Figure 4.6. The most obvious feature in this figure is correspondence of water levels between well W21 and the Discharge Channel. Timing and magnitude of water level changes match exceedingly well. The continuous water level data are too coarse to allow exact time-matching between these two locations (i.e., measurements frequency was hourly at W21 and 20 minutes at the channel). However, data is sufficient to indicate that well W21 responds to changes in Discharge Channel water levels in less than two hours. Noting that well W21 is located 285 ft from the head of the Discharge Channel, hydraulic pressure changes via natural porous media at the site would not produce these types of responses. Results indicate the presence of a subsurface feature(s) residing at depth (<679 ft-msl) providing relatively direct connection between these two locations. Given the correlation in groundwater levels between wells W21 and 31 (Figure 4.4), this or another feature(s) also extends to the vicinity of well 31 (145 ft from the head of the channel).

Figure 4.7 presents continuous water level data at wells W21, 14, and the Discharge Channel for the interval 11/17/06 – 01/24/07. Of interest in this figure is the precipitous change in well W21 groundwater levels coincident with the beginning and ending of the plant outage from 11/26/06 – 12/24/06. Also noted is the anomalous departure of correlation between well W21 and the Discharge Channel from 12/05/06 – 12/15/06 during the outage interval. Daily operations log entries were examined in attempts to identify any major water transfers that might be associated with rapid changes in groundwater levels (e.g., RWST and Spent Fuel Pool transfers). There is no evidence of changes in groundwater levels associated with such transfers.



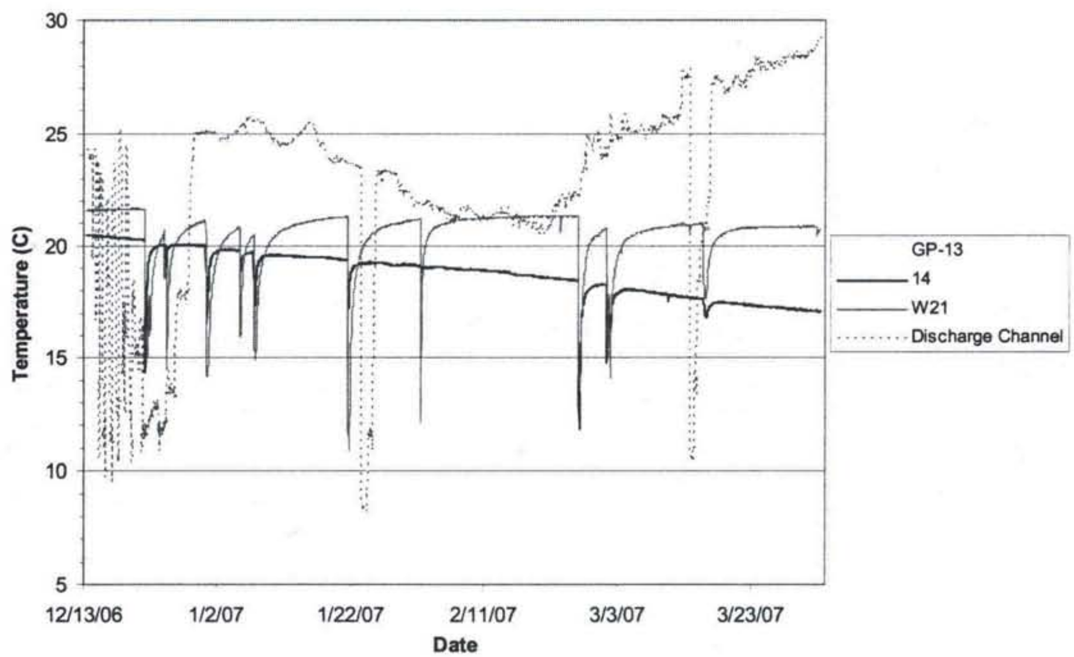


Figure 4.6 Continuous Water Levels (Top) and Temperatures (Bottom) at Wells GP-13, 14, W21, the Discharge Channel, and the River

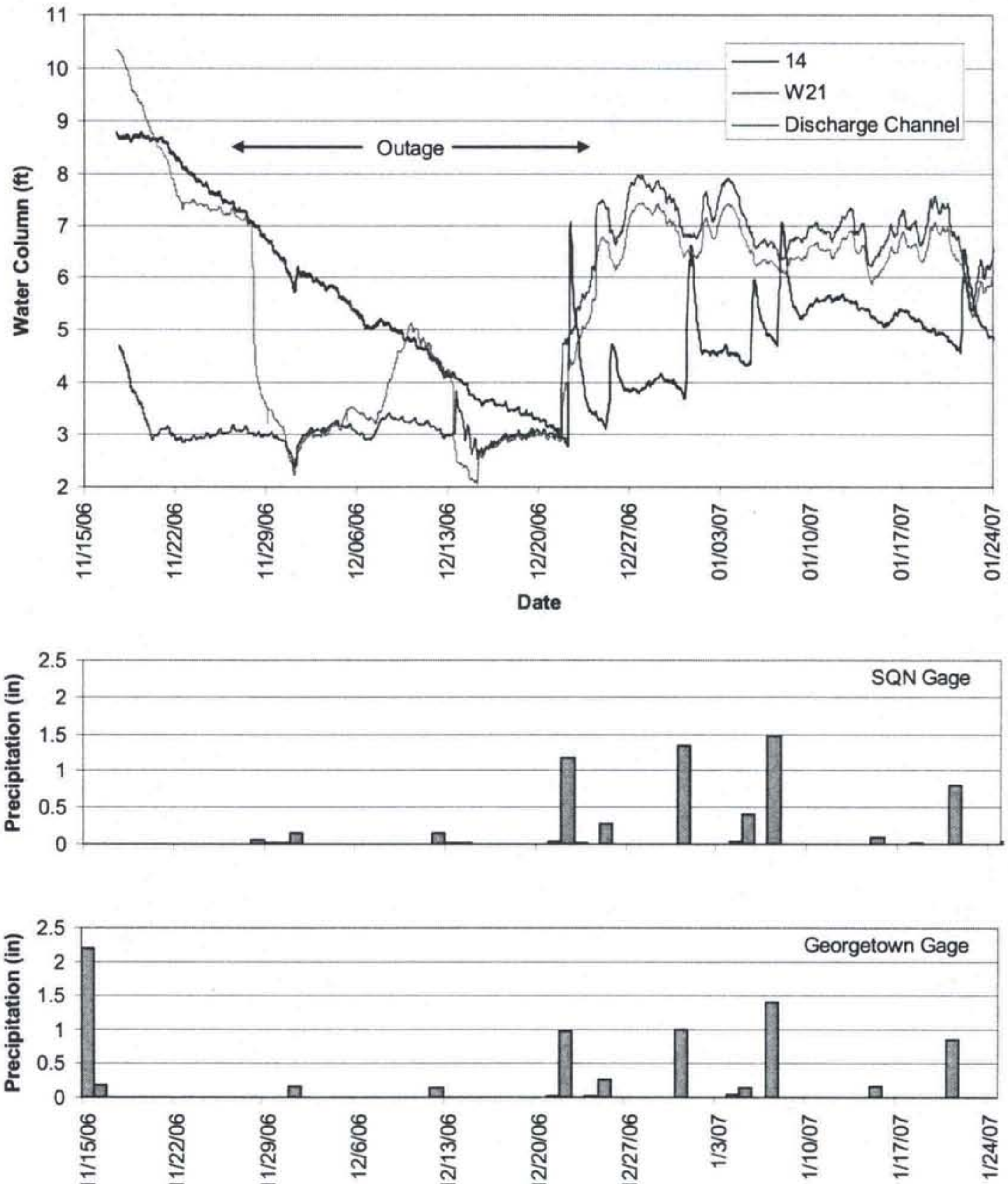


Figure 4.7 Continuous Water Levels (Top) and Precipitation (Bottom) at Wells 14, W21, and the Discharge Channel

Well 14 experiences abrupt weekly to biweekly groundwater level increases (Figures 4.6 and 4.7) over most of the monitoring period. The water level changes are correlated with pronounced water temperature decreases (Figure 4.6). Precipitation data from the plant meteorological station and from the Georgetown gage (9 miles NE of SQN) were obtained and are shown at the bottom of Figure 4.7. As shown, groundwater level and temperature changes at well 14 are clearly linked with rainfall events. It is highly probable that the well 14 wellhead seal has been damaged and that rainfall runoff is directly entering the well annulus at this location. Similar results are observed in temperature data at well W21. Again, data suggests that well W21 wellhead seal has been damaged.

Figure 4.8 depicts the potentiometric surface at the site based on April 02, 2007 groundwater level measurements. Groundwater movement is northerly over the Unit 1 portion of the site with the Intake Channel serving as a primary surface water control to hydraulic gradients. Over the Unit 2 side of the site, groundwater movement is primarily southerly with convergent flow toward the Discharge Channel.

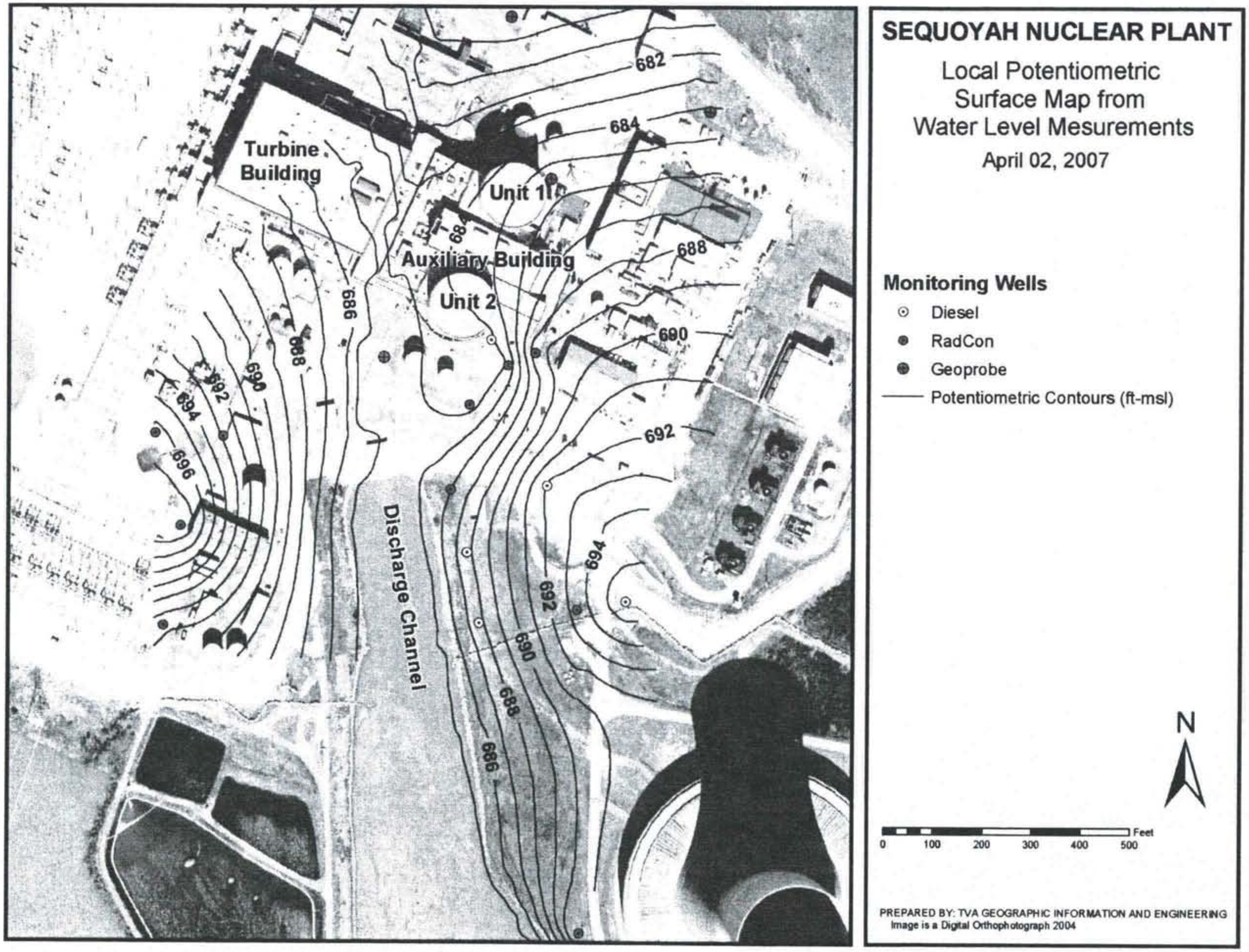


Figure 4.8 Local Potentiometric Surface from April 02, 2007 Water Level Measurements

4.5 Interior Sampling

Groundwater inleakage occurs at SQN along concrete construction joints, poorly sealed pipe sleeves, concrete factures, and other locations. During this investigation, several areas were visually inspected and groundwater inleakage samples were collected for tritium analyses. Inspection locations were selected based on historical observations of seepage, depth, and location (i.e., below groundwater table and in vicinity of observed tritium), and accessibility. Locations identified for inspections and sampling included the Auxiliary Building, north wall of the Turbine Building, and RWST pipe tunnels for both units.

Groundwater inleakage has been documented at SQN since 1978 (TVA, 1978). At this time, groundwater inleakage was described in the Auxiliary Building. At the request of SQN, an inspection of the Auxiliary Building inleakage problem was performed by J. M. Boggs of TVA's Engineering Laboratory during May 1997. Inleakage locations were identified on plant drawings and catalogued with photographs (Figure 4.9).

As shown in Figure 4.9, twelve inleakage locations have been identified in the Auxiliary Building at floor elevations 653 and 669 ft-msl. Red symbols identified locations where inleakage rates were sufficiently high in 1997 to require collection. Blue symbols identified locations of low inleakage rates not requiring collection. These locations are listed in Table 4.4. Two additional inleakage locations not identified in Figure 4.9 and Table 4.4 were documented (1997) at a leaking conduit in the Unit 1 UHI pit and at a 4-inch diameter pipe sleeve near elevation 655 ft-msl of the UHI pit.

Table 4.4 Auxiliary Building Groundwater Inleakage Locations

Location	Remarks
1	Elevation 653 ft-msl pipe chase, high inleakage rate
2	Seepage being collected, moderate inleakage rate
3	Two inleakage locations, drip funnels being used for collection
4	no comment
5	no comment
6	Leak at concrete construction joint
7	Leak above floor in wall
8	Patched
9	Leak at floor
10	no comment
11	no comment

Sampling of groundwater inleakage from the north wall of the Turbine Building (near elevation 662 ft-msl) was conducted on 10/20/06. Analysis by WARL indicated that tritium was less than the MDC of 220 pCi/L.

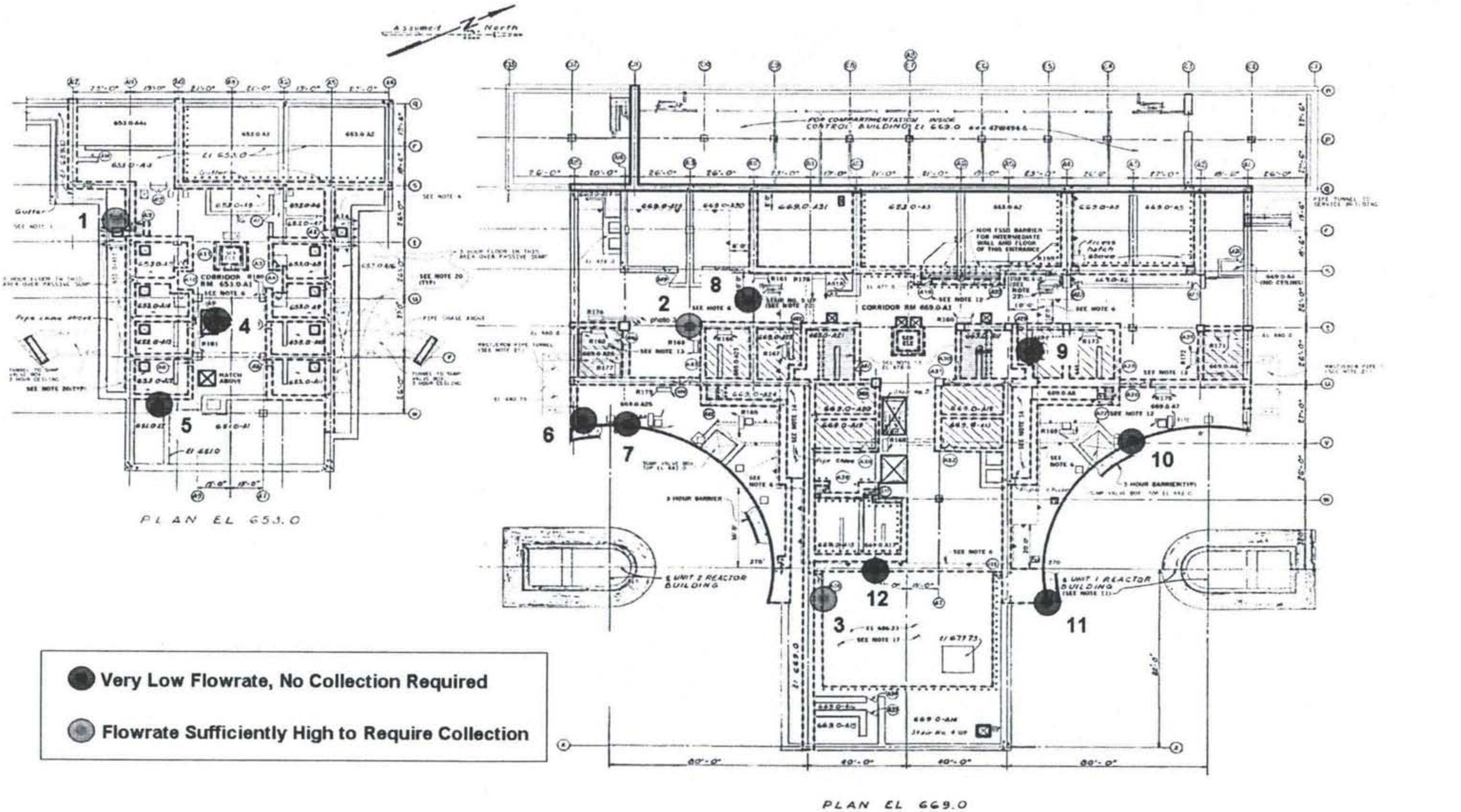


Figure 4.9 Groundwater Inleakage Locations at Auxiliary Building

Inspection and sampling within the Unit 1 and 2 RWST pipe tunnels was performed by SQN staff under work orders 06-776301-000 and 06-776302-000 during 8/28/06 and 8/31/06. Groundwater inleakage samples were collected from tunnel walls and water samples were collected from trough drains at each location. Analyses by WARL indicated that tritium was less than the MDC of 220 pCi/L for all samples.

Based on comparable tritium investigations completed at WBN, and similarity of SQN plant design to WBN, inspection of Unit 1 and 2 Annuli and transfer tube bellows are being performed by SQN staff. These inspections involve boroscope methods and removal of concrete block shield walls for access. Where possible, samples are being collected for analyses. These investigations are continuing and results are forthcoming.

5.0 RESULTS AND RECOMMENDATIONS

5.1 Tritium Distribution

5.1.1 Manual Sampling

Manual sampling at 20 catch basins, vaults, and manholes (Figure 4.1; Table 4.2) during this study showed positive detection of tritium at four shallow locations. The sampling depths at these locations were >15 ft above the groundwater table. Tritium was observed at SS-6 (8,879 pCi/L), SS-14 (425 pCi/L), SS-21 (284 pCi/L), and SS-22 (312 pCi/L). All other samples were less than the MDC.

Observation of tritium in catch basin SS-6 (2.6 ft deep) near the Service Building is not completely explicable. The observed tritium concentration is an order of magnitude greater that tritium concentrations observed in groundwater from Geoprobe borings (GP-1 – GP-4) in the immediate vicinity. Results suggest that the observed tritium concentration might be associated with direct discharges to the single line entering this catch basin.

The low tritium concentration at catch basin SS-14 (1.9-ft deep), near the 12-inch waste condensate line, is similar to tritium concentrations observed for soil wells located along the condensate line. The 12-inch condensate line is located above ground at this location and leaks to ground surface could produce the observed concentration. Likewise, overflows from the Turbine Building sump could produce similar results.

The low tritium concentration observed at catch basin SS-22 (7.8 ft deep) may be the result of a release from the MFTDS (Section 2.3) that occurred in 1997. A correspondingly low tritium concentration at the SS-21 TV box sump (2.6-ft deep) may also be the results of the MFTDS release. However, this vault possesses an impermeable cover. It is conceivable that the source of tritiated water within the SS-21 sump is associated with contaminated groundwater some distance upgradient (west) of the electrical vaults. Electrical conduits (and their bedding materials) intersecting such vaults are probable avenues for shallow groundwater transport.

Manual sampling of several selected locations was performed during January 2004 to support siting of RadCon wells located along 12-inch waste condensate line. Water sampling results at all locations indicated tritium concentrations <MDC of 220 pCi/L. Sampling locations included:

- Diesel Fuel Oil Interceptor Trench discharge;
- Turbine Building sump;
- Low-Volume Waste Treatment Pond inlet;
- Condensate water discharge from Turbine Building roof to sump;
- CO_2 vault sump south of Turbine Building;
- Alum Sludge Ponds A (west) and B (east);

- Water Treatment Plant basement sump;
- Storm drain #45 north of High Pressure Fire Protection System tanks;
- Storm drain #44 east of Water Treatment Plant;
- Storm drain #46 south of Unit 2 Condensate Storage Tanks.

5.1.2 Groundwater Sampling

From 1998 through 2001, tritium was consistently observed at concentrations ranging from 401 to 2,120 pCi/L at well W5 (Figure 1.2). No further tritium detection has been observed at well W5 since 2001. Beginning in February 2002, TVA expanded REMP groundwater monitoring at SQN (Section 1.3) with the addition of 12 soil monitoring wells and collection of groundwater samples from existing wells in proximity to known areas of tritium contamination. Since August 2003, 206 groundwater sampling events have been conducted at one or more of these wells. Tritium concentrations observed from these sampling events are tabulated in Appendix B.

As shown in Appendix B, tritium concentrations measured at wells 24-28, 30, and 32-35 have been <MDC with only a few exceptions near the MDC. Relatively high tritium concentrations (2,576 – 19,750 pCi/L) have been continuously observed at well 31 since May 2004. As shown in Figure 5.1 tritium concentrations are generally correlated with groundwater levels at well 31.

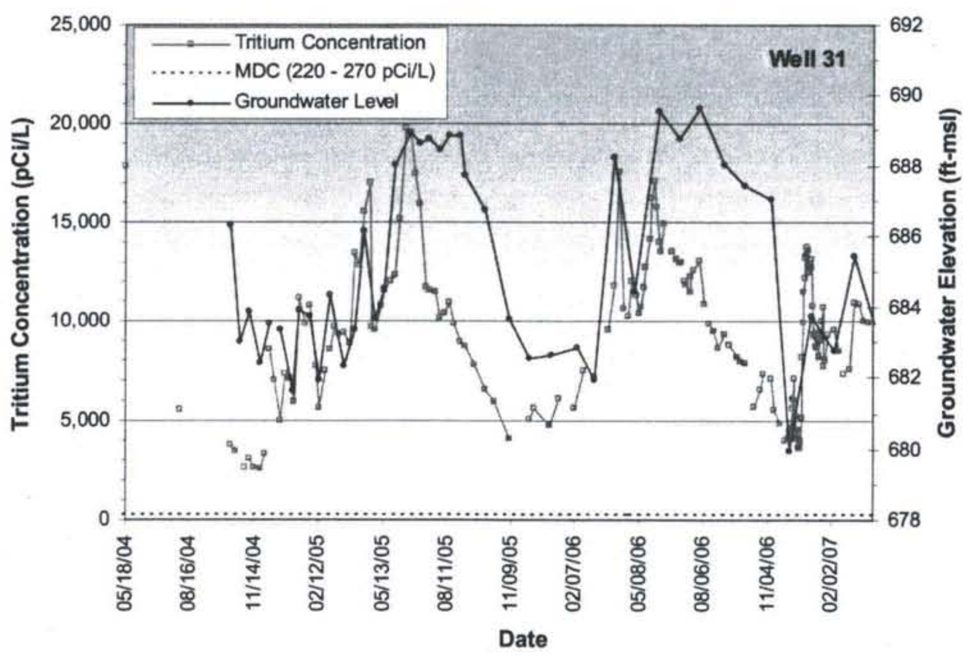


Figure 5.1 Time-Series Tritium Concentrations and Groundwater Levels at Well 31

At well W21, tritium concentrations have ranged from 226 – 9080 pCi/L since sampling commenced in February 2004. As shown in Figure 5.2, there is no correlation between tritium concentrations and groundwater levels at well W21. Low tritium concentrations have also been consistently observed at well 27 (<500 pCi/L) and well 29 (<1800 pCi/L) with no relationships between tritium and groundwater levels at either location (Figure 5.3).

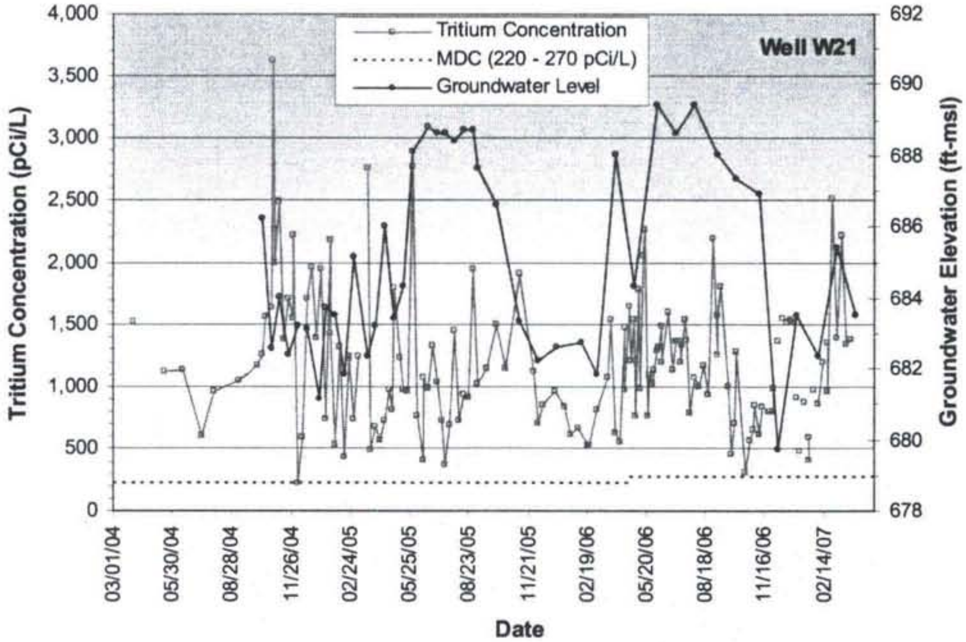
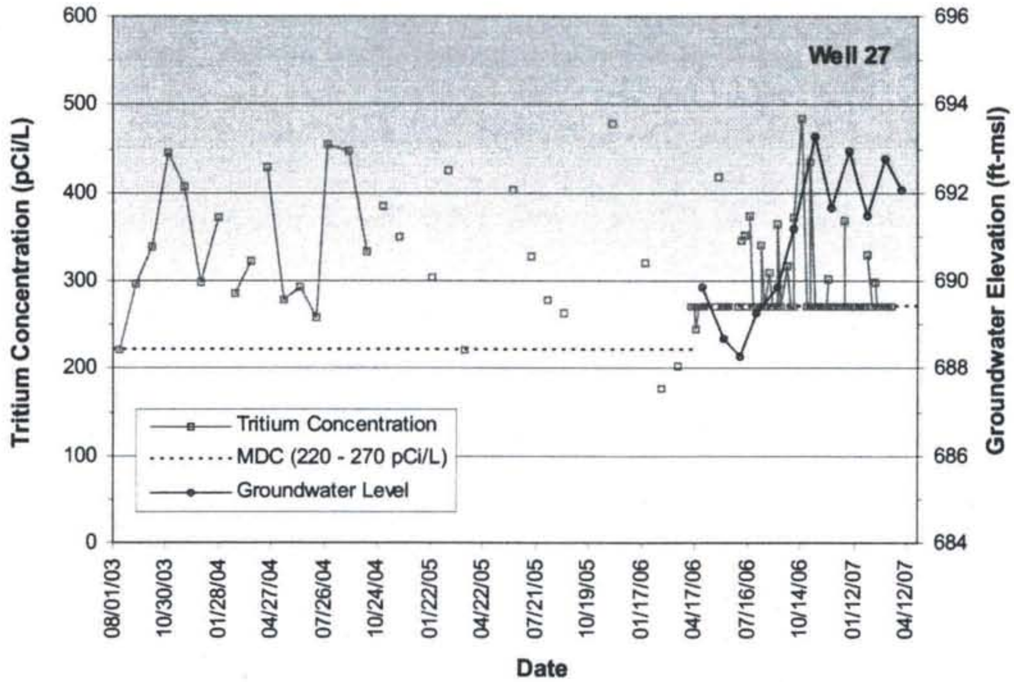


Figure 5.2 Time-Series Tritium Concentrations and Groundwater Levels at Well W21

Groundwater sampling at 23 Geoprobe borings (Figure 4.2; Table 4.3) indicated low tritium concentrations (274 – 661 pCi/L) in borings (GP-1 – GP-7) surrounding the Unit 1 RWST. Borings GP-21, GP-22, GP-25, and GP-26 exhibited low tritium concentrations (332 – 2700 pCi/L) in the area S-SE of Unit 2. Boring GP-28, just east of this area, provided a similarly low tritium concentration (394 pCi/L). The highest tritium concentration observed within all Geoprobe borings occurred at GP-13 (16, 211 pCi/L). Due to the relatively high groundwater tritium concentration at GP-13, a soil monitoring well was installed at this location and additional groundwater sampling was conducted. Figure 5.4 depicts sampling results to date.



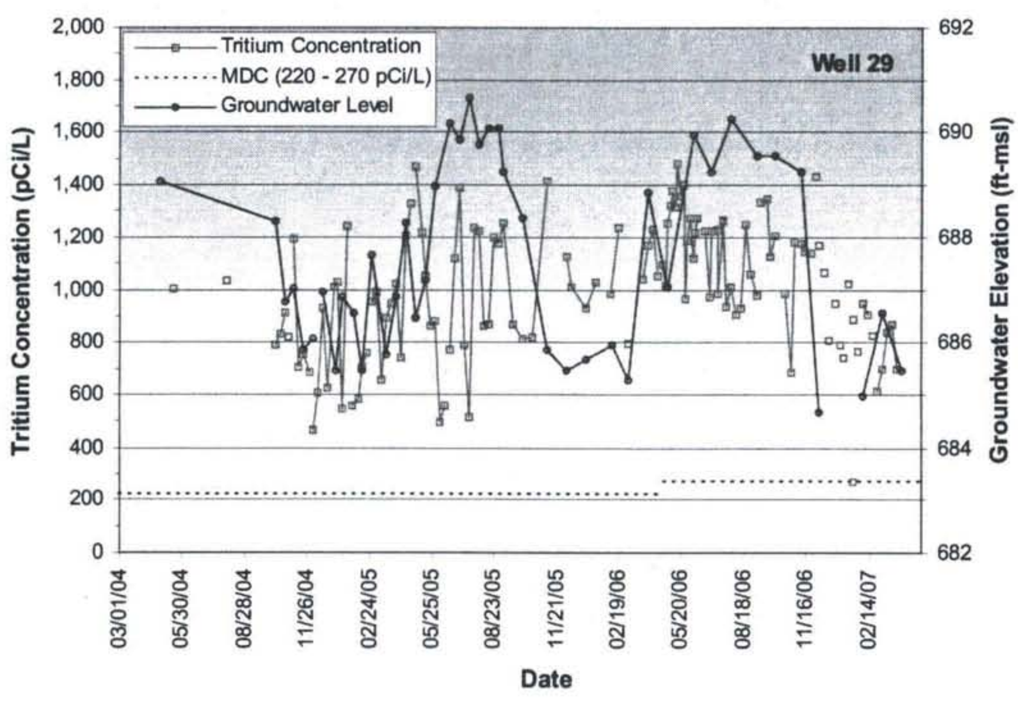


Figure 5.3 Time-Series Tritium Concentrations and Groundwater Levels at Wells 27 and 29

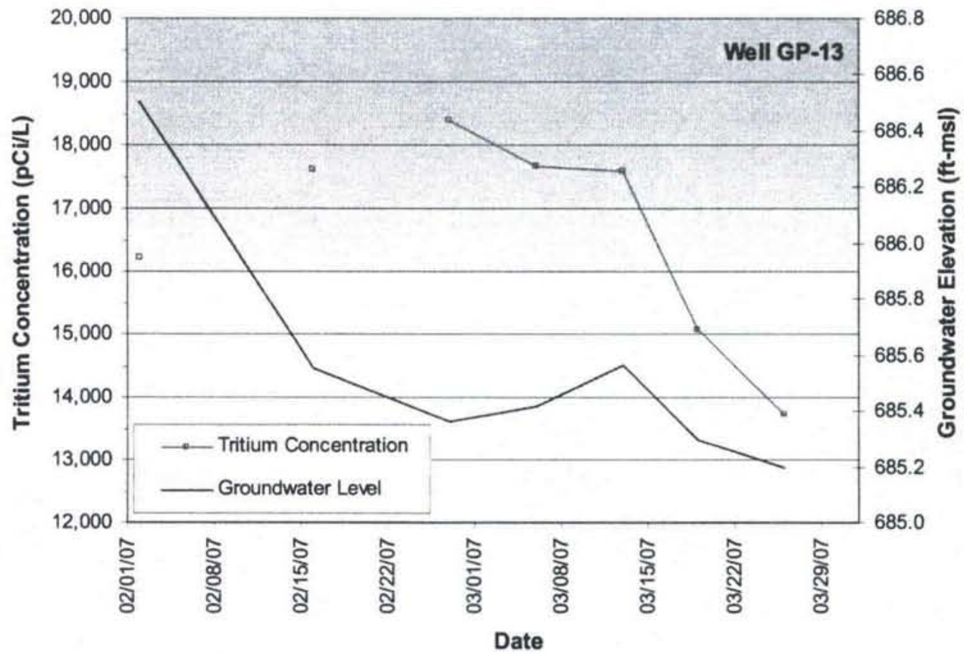


Figure 5.4 Time-Series Tritium Concentrations and Groundwater Levels at Well GP-13

Figure 5.5 shows the distribution of tritium based on shallow (soil) groundwater sampling during January and February 2007. In general, the highest tritium concentrations in the shallow groundwater system are associated with two distinct areas north and south of Units 1 and 2. Although data is sparse for the deeper flow regime (i.e., weathered bedrock and shallow bedrock), the extent of the tritium plume is reasonably bounded by sampling locations in the horizontal.

5.2 Tritium Sources

Current results suggest that sources of tritiated groundwater are primarily associated with past inadvertent releases of liquids containing radioisotopes. Relatively high groundwater tritium concentrations have been observed at wells 31 and GP-13, noting that there have been no observations exceeding the EPA Drinking Water Standard of 20,000 pCi/L for tritium (40 CFR 141.25).

Historically, remediation procedures for inadvertent liquid releases have chiefly involved the collection and screening of soil samples and limited water samples for radionuclides. However, the radionuclide analytes exclude short-lived isotopes such as tritium (see Section 2.3). Likewise, groundwater sampling associated with inadvertent liquid releases was not conducted during remediation. There is therefore a strong likelihood that tritium contamination from inadvertent liquid releases was not revealed due to the limitations of sampling and analytical protocols.

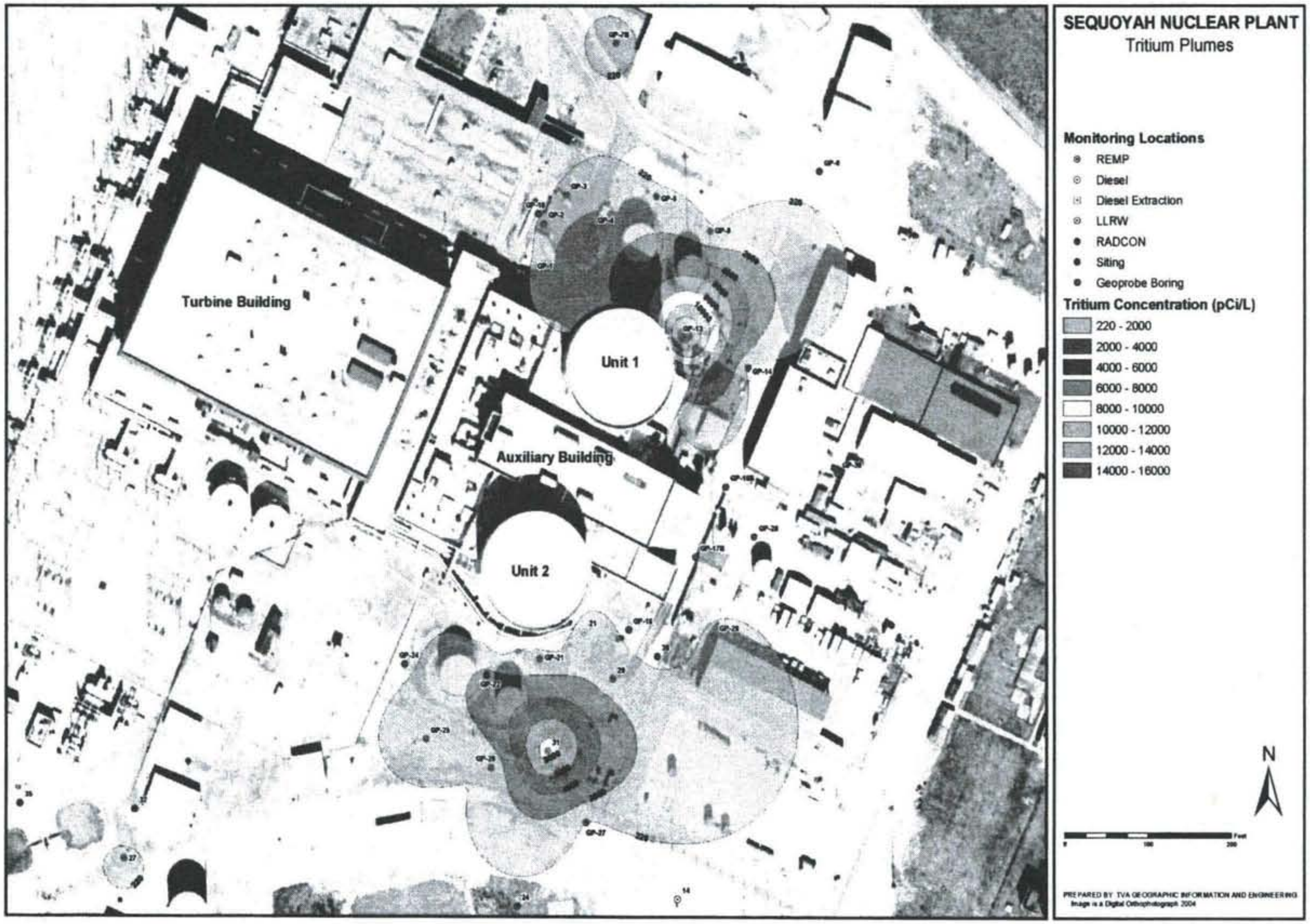


Figure 5.5 Spatial Distribution of Tritium from Groundwater Sampling During January and February 2007

An analog groundwater investigation of tritium releases at WBN suggests that leaks through the fuel transfer tube and seismic gap (between Unit 2 Reactor and Auxiliary Buildings) contaminated groundwater at the WBN site. Tritium concentrations in these source areas are nearly 100 million pCi/L and the release of only a small volume of water is necessary to produce elevated tritium concentrations in site groundwater. Inspections of SQN Unit 1 and 2 fuel transfer tubes, spent fuel pool, and associated components are currently being performed by SQN staff. These investigations are continuing and results are forthcoming.

Controlled airborne releases from the plant ventilation system may result in measurable atmospheric deposition of plant-related radionuclides (including tritium) in the vicinity of the site. Since this potential tritium source is not likely to be a major contributor to groundwater contamination, airborne release was not evaluated during this investigation.

Unit 1 – Elevated tritium concentrations in groundwater north of Unit 1 suggest that the inadvertent water release from the MFTDS in 1997 (see Section 2.3) is likely the primary source of shallow groundwater contamination in this vicinity. The estimated volume of water released by the MFTDS is 600 – 1,000 gallons. A secondary source of tritium contamination in this vicinity is related to relatively small volumes of water that drain from the RWST moat and have discharged to ground surface for >25 years. Observation of tritium in catch basin SS-6 near the Service Building is not completely explicable, but results suggest that the observed tritium concentration might be associated with direct discharges to the single line entering this catch basin.

Unit 2 – Tritium concentrations in groundwater south of Unit 2 suggest that inadvertent releases from the Unit 2 CDWE and additional Equipment Buildings (see Section 2.3) have contaminated shallow groundwater in this vicinity. A tertiary source of tritium contamination in this vicinity is related to the moat drain from the RWST that discharged to ground surface for >25 years. Tritium concentrations at well 27 appear to be of an isolated nature and may be related to leakage of the 12-inch waste condensate line.

5.3 Tritium Transport and Fate

Tritium is a conservative contaminant – it is not susceptible to attenuation via sorption or biochemical degradation. Reduction of tritium concentrations in the groundwater system at SQN will occur primarily by hydrodynamic dispersion and dilution. The dispersion process is related to variations in groundwater velocity that occur on a microscale by differences in media porosity and on a macroscale by variations in hydraulic conductivity. Dispersion will result in reductions of tritium concentrations with increasing distance from the source (e.g., the MFTDS railroad bay). Dispersion will be more pronounced in the soil horizon relative to the deeper and more transmissive weathered bedrock horizon. However, the fate and transport of tritium in the site groundwater system is also likely to be governed by avenues of relatively rapid groundwater movement that exist within bedding material of larger pipelines and tunnels, and possibly along the weathered bedrock horizon.

Groundwater and surface water level measurements during the study confirm that the Intake and Discharge Channel will ultimately be recipient to tritiated groundwater discharge from the site. Dilution ratios in the channels and subsequently the Tennessee River are dependent on plant operation and river flows.

5.4 Recommendations

No active remediation is recommended for the site due to the limited extent of tritium contamination, tritium concentrations in groundwater less than EPA Drinking Water Standard of 20,000 pCi/L (40 CFR 141.25), perceived low exposure and dose risks, and negligible potential for offsite groundwater migration. The following recommendations are submitted based on findings of this investigation.

Source Terms: Spatial data and anecdotal evidence suggest that tritium sources are primarily associated with past inadvertent releases of liquids containing radioisotopes. Additional groundwater sampling in the areas of GP-13 would assist in bounding the tritium plume on the north (Unit 1) side of the site. Sampling would involve the installation of 6 – 8 shallow soil borings to confirm the extent of tritium contamination.

There are no bedrock borings located in close proximity to Units 1 and 2 that can be used to examine the vertical distribution of tritium that might extend into the shallow Conasauga bedrock. Two bedrock borings extending into the upper 20 ft of bedrock are recommended for the zones exhibiting relatively high tritium concentrations (north and south of Units 1 and 2). Results should be examined collectively to verify that higher tritium concentrations do not exist at excessive concentrations within the shallow bedrock flow system.

It is likely that tritium contamination from inadvertent liquid releases was not revealed in past investigations due to the limitations of sampling and analytical protocols. SQN procedures directed towards investigation and remediation of future releases should be developed or modified to identify short-lived isotopes such as tritium. Confirmatory sampling of environmental media following remediation of a spill should meet the MDCs of applicable regulatory criteria. In most cases, a professional engineer with expertise in hydrogeology should be consulted to assist in remediation investigations.

The components investigation currently being conducted by SQN staff should continue to substantiate that no releases to groundwater have occurred from internal sources. Should problems be identified, their remedies should extend to external environs as necessary.

Routine Onsite Groundwater Monitoring: Routine groundwater quality and water level monitoring should be continued at a quarterly frequency at wells 31, GP-13, and W21 for a minimum of two years. These data should be reviewed on an annual basis by a professional engineer with expertise in hydrogeology and groundwater science. In addition to tritium, boron should be considered as an analyte since it is typically added to primary cooling water as a neutron moderator. Therefore, when detected at concentrations greater than background, boron can be an indicator of leaks from primary systems. Results of routine groundwater sampling should be reviewed annually by a professional engineer with expertise in hydrogeology.

Groundwater sampling protocols have been prepared by TVA and standard forms are available for use. In addition, the NRC (1979) and ASTM (2006) provide standard guidelines for groundwater sampling. The SQN staff should assure that acceptable groundwater sampling protocols are being utilized. In addition to groundwater collection methods, these practices also extend to: sample handling, labeling, storage, shipment and chain-of-custody procedures; qualification and training requirements for sampling personnel; applicable regulatory limits; analytical methods and MDCs, required analytical method uncertainties; quality control samples and acceptance criteria; required number of samples per analytical batch; and validation methods.

REMP Onsite Groundwater Monitoring: Bedrock well W5 is currently the only onsite well being used for REMP groundwater monitoring purposes. The well location and type is poorly suited for rapid detection of groundwater contamination from primary plant systems. Well W5 resides too far from the plant, is situated adjacent to the Intake Channel, and is developed in bedrock. Consideration should be given to an alternate well location(s) and type (e.g., well immediate to the site, along groundwater gradient, and appropriately screened).

Data Management and Quality: The current data management procedures result in significant difficulties related to groundwater data acquisition and authentication. TVA and SQN should consider a programmatic evaluation of data management and quality practices to ensure that analytical results are documented, retained, and readily retrievable. At a minimum, documented analytical data shall contain the following information:

- Sample identification (e.g., location and well identification);
- Sample date and time;
- Measured concentration for all radionuclides where results have been reported (whether or not above the detection criteria, or positive or negative);
- Measurement uncertainty;
- Achieved MDCs;
- Records of data validation and verification;
- Identification of missing sample results;

- Analytical method(s).

Development of a database should be considered that meets criteria described in American Nuclear Insurers Information Bulletin 80-1A. The database developed by TVA for the fossil fuel groundwater monitoring program would serve as an ideal platform for groundwater data management.

Well Protection and Abandonment: Analytical results from repeated sampling at several site wells indicate that they can be abandoned. Wells that are deemed of no strategic importance have not exhibited tritium concentrations >MDCs and are in close proximity to other monitoring wells. Wells recommended for abandonment include: 30, 32, 34, 35, UN1W, UNW2, and UNW3.

Wells installed for monitoring along the waste condensate lines and during this study do not possess well head protection. Lockable well head protective covers, balusters, and/or flush-mount covers should be installed at these wells. Data suggest that wells 14 and W21 well head seals have been damaged, allowing direct entry of rainfall runoff. These well heads should be repaired.

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APPENDIX A

WELL CONSTRUCTION LOGS

ROCK MONITORING WELL INSTALLATION RECORD

PROJECT: SEQUOYAH NUCLEAR PLANT

WELL NUMBER: W1

INSTALLATION DATE:

PLANT COORDINATES EAST: -1272.6 ft

NORTH: 800.1 ft

GROUND SURFACE ELEVATION: 705.6 ftmsl

TOP OF INNER CASING: 708.87 ftmsl

BACKFILL MATERIAL: SAND & PEA GRAVEL

CASING DIAMETER: 6"

CASING MATERIAL: SOLID STEEL CASING

DRILLING TECHNIQUE IN ROCK: PERCUSSION

DRILLING TECHNIQUE IN SOIL: AUGER

DRILLING CONTRACTOR:

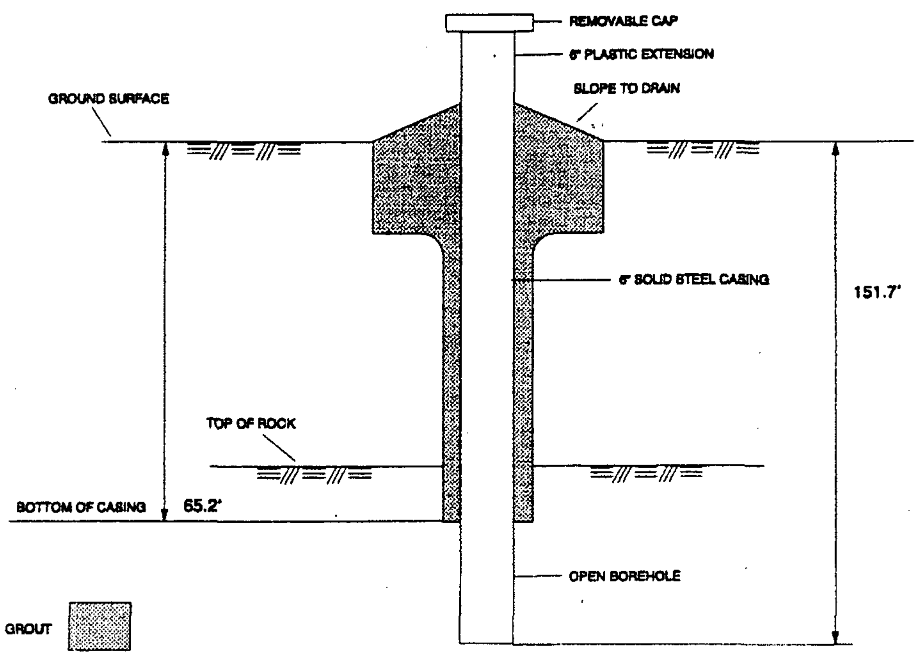
OUTER BOREHOLE DIAMETER:

OPEN BOREHOLE DIAMETER: 6"

LOCKABLE COVER ?: NO

COMMENTS: PLASTIC PIPE ADDED TO RAISE THIS WELL 4.37 ft.

(NOT TO SCALE)



ENG LAB 7/25/91

MONITORING WELL INSTALLATION RECORD

PROJECT: SEQUOYAH NUCLEAR PLANT

WELL NUMBER: W2

INSTALLATION DATE:

PLANT COORDINATES EAST: -1105.5 ft

NORTH: -1271.6 ft

GROUND SURFACE ELEVATION: 700.1 ftmsl

TOP OF INNER CASING: 700.91 ftmsl

BACKFILL MATERIAL: SAND & PEA GRAVEL

CASING DIAMETER: 6"

CASING MATERIAL: SOLID STEEL CASING

DRILLING TECHNIQUE IN ROCK: PERCUSSION

DRILLING TECHNIQUE IN SOIL: AUGER

DRILLING CONTRACTOR:

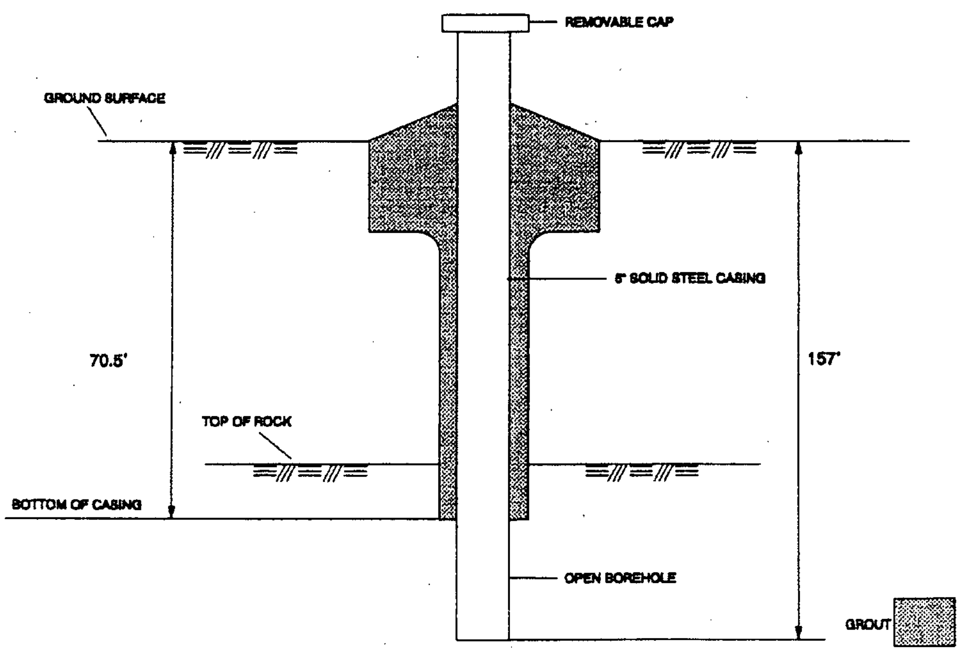
OUTER BOREHOLE DIAMETER:

OPEN BOREHOLE DIAMETER: 6"

LOCKABLE COVER ?: NO

COMMENTS: NEAR GAS/DIESEL TANKS

(NOT TO SCALE)



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MONITORING WELL INSTALLATION RECORD

PROJECT: SEQUOYAH NUCLEAR PLANT

WELL NUMBER: W4

INSTALLATION DATE:

PLANT COORDINATES EAST: 948.1 ft

NORTH: 39.6 ft

GROUND SURFACE ELEVATION: 732.3 ftmsl

TOP OF INNER CASING: 742.27 ftmsl

BACKFILL MATERIAL: SAND & PEA GRAVEL

CASING DIAMETER: 6"

CASING MATERIAL: SOLID STEEL CASING

DRILLING TECHNIQUE IN ROCK: PERCUSSION

DRILLING TECHNIQUE IN SOIL: AUGER

DRILLING CONTRACTOR:

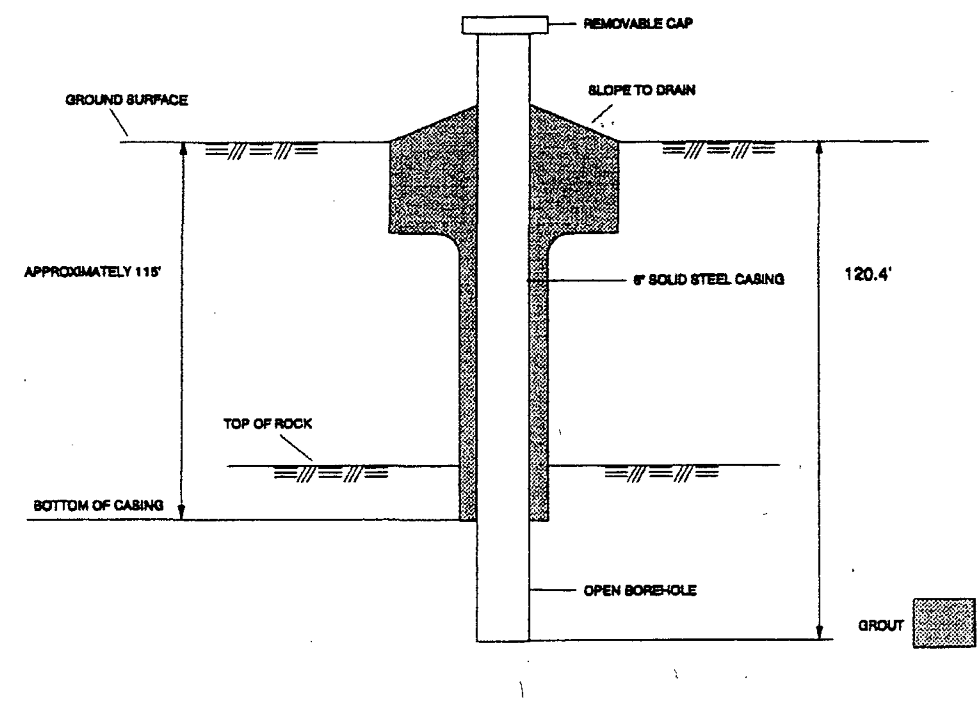
OUTER BOREHOLE DIAMETER:

OPEN BOREHOLE DIAMETER:

LOCKABLE COVER ?

COMMENTS:

(NOT TO SCALE)



ENG LAB 7/25/91

TENNESSEE VALLEY AUTHORITY
River System Operations & Environment
Research & Technology Applications
Environmental Engineering Services - East

SEQUOYAH NUCLEAR PLANT

INVESTIGATION OF TRITIUM RELEASES TO GROUNDWATER

Hank E. Julian, P.E., P.G.

Geosyntec
consultants

engineers | scientists | innovators

and

Matthew Williams

Knoxville, Tennessee
May 2007

TABLE OF CONTENTS

LIST OF FIGURES

Acronyms and Abbreviations

CBI	Chicago Bridge & Iron
CCW	Condenser Circulating Water
CDWE	Condensate Demineralizor Waste Evaporator
CVCS	Chemical and Volume Control System
EPA	Environmental Protection Agency
ERCW	Essential Raw Cooling Water
GIS	Geographic Information System
GWSI	Ground-Water Site Inventory
LLRWSF	Low Level Radwaste Storage Facility
MDC	Minimum Detection Concentration
MFTDS	Modularized Transfer Demineralization System
MWe	Megawatt Electric
MWt	Megawatt Thermal
NEI	Nuclear Energy Institute
NRC	Nuclear Regulatory Commission
NRWT	Nonreclaimable Waste Tank
NT	Neutralization Tank
ODCM	Offsite Dose Calculation Manual
pCi/L	Picocuries per liter
PER	Problem Evaluation Report
Rad DI	Radwaste Demineralizer System
RCA	Radiation Control Area
REMP	Radiological Environmental Monitoring Program
RWST	Refueling Water Storage Tank
SQN	Sequoyah Nuclear Plant
TRM	Tennessee River Mile
TVA	Tennessee Valley Authority
USGS	United State Geological Survey
WARL	Western Area Radiological Laboratory
WBN	Watts Bar Nuclear Plant

1.0 INTRODUCTION

1.1 Purpose and Objectives

The Tennessee Valley Authority (TVA) is committed to controlling licensed material, minimizing potential unplanned, unmonitored releases to the environment from plant operations, and minimizing long-term costs associated with potential groundwater and subsurface contamination. Although current public health standards and limits are deemed appropriate, they may not satisfy public trust issues when unplanned releases occur. In conjunction with the Nuclear Energy Institute (NEI), TVA has approved a voluntary policy to enhance detection, management and communication about inadvertent radiological releases in groundwater. The investigation described herein represents an initial step in policy implementation.

In August 2006, a team consisting of GeoSyntec Consultants, Sequoyah Nuclear Plant (SQN) staff, and corporate TVA personnel was established to locate potential source(s) of site tritium releases and to identify potential migration route(s) to groundwater. This report provides findings of the site subsurface investigation with recommendations for the path forward. The primary objectives of the investigation were to:

- Identify potential radionuclide contaminant sources that account for observed measurements,
- Assess the nature and extent of subsurface tritium contamination, and
- Characterize groundwater movement to evaluate potential contaminant migration routes.

Tasks associated with this investigation included:

- Comprehensive review of historical radiological release information,
- Review of site drawings and plant construction photographs,
- Installation and sampling of soil borings and groundwater monitoring wells,
- Enhanced sampling of existing monitoring wells,
- Visual inspections and manual sampling of yard drains, sumps, manholes, and internal seeps,
- Manual and continuous water level monitoring, and
- Internal components investigations of both units using visual and boroscope methods.

1.2 Plant Description

SQN is a two-unit nuclear power plant located approximately 7.5 miles northeast of Chattanooga at the Sequoyah site in Hamilton County, Tennessee. The plant has been designed, built, and is operated by TVA. Each of the two identical units (Units 1 and 2; Figure 1.1) employs a Pressurized Water Reactor Nuclear Steam Supply System with four coolant loops furnished by Westinghouse Electric Corporation. These units are similar to those of TVA's Watts Bar Nuclear Plant.

Each of the two reactor cores is rated at 3,455 MWt and, at this core power, each unit will operate at 3,467 MWt. The additional 12 MWt is due to the contribution of heat of the Primary Coolant System from nonreactor sources, primarily reactor coolant pump heat. The total generator output is 1,199 MWe for the rated core power. The containment for each of the reactors consists of a freestanding steel vessel with an ice condenser and separate reinforced Concrete Shield Building. The ice condenser was designed by the Westinghouse Electric Corporation. The freestanding containment vessel was designed by Chicago Bridge & Iron (CBI). Unit 1 began commercial operation on July 1, 1981. Unit 2 began commercial operation on June 1, 1982.

1.3 Historical Tritium Monitoring

As part of the SQN onsite Radiological Environmental Monitoring Program (REMP), quarterly groundwater monitoring for tritium began in 1971 at four bedrock monitoring wells (W1, W2, W4, and W5) located along the perimeter of the site (Figure 1.2). Onsite REMP groundwater monitoring was reduced to a single well (W5) in 1980. Tritium was initially observed in SQN groundwater at well W5 from 1989 sampling at a background concentration of 379 picocuries per liter (pCi/L). No other detection of tritium was observed at well W5 until 1998. From 1998 through 2001, tritium was consistently observed at concentrations ranging from 401 to 2,120 pCi/L at well W5. No further tritium detection has been observed at well W5 since 2001.

Evaluation of REMP data indicates no evidence of tritium or other radionuclides exceeding detection levels in offsite surface water or groundwater samples since 1992. Pre-1992 tritium concentrations in offsite surface water and groundwater samples reflect ambient concentrations resulting most probably from cosmogenic sources and nuclear weapons testing from the 1940s through the 1970s.

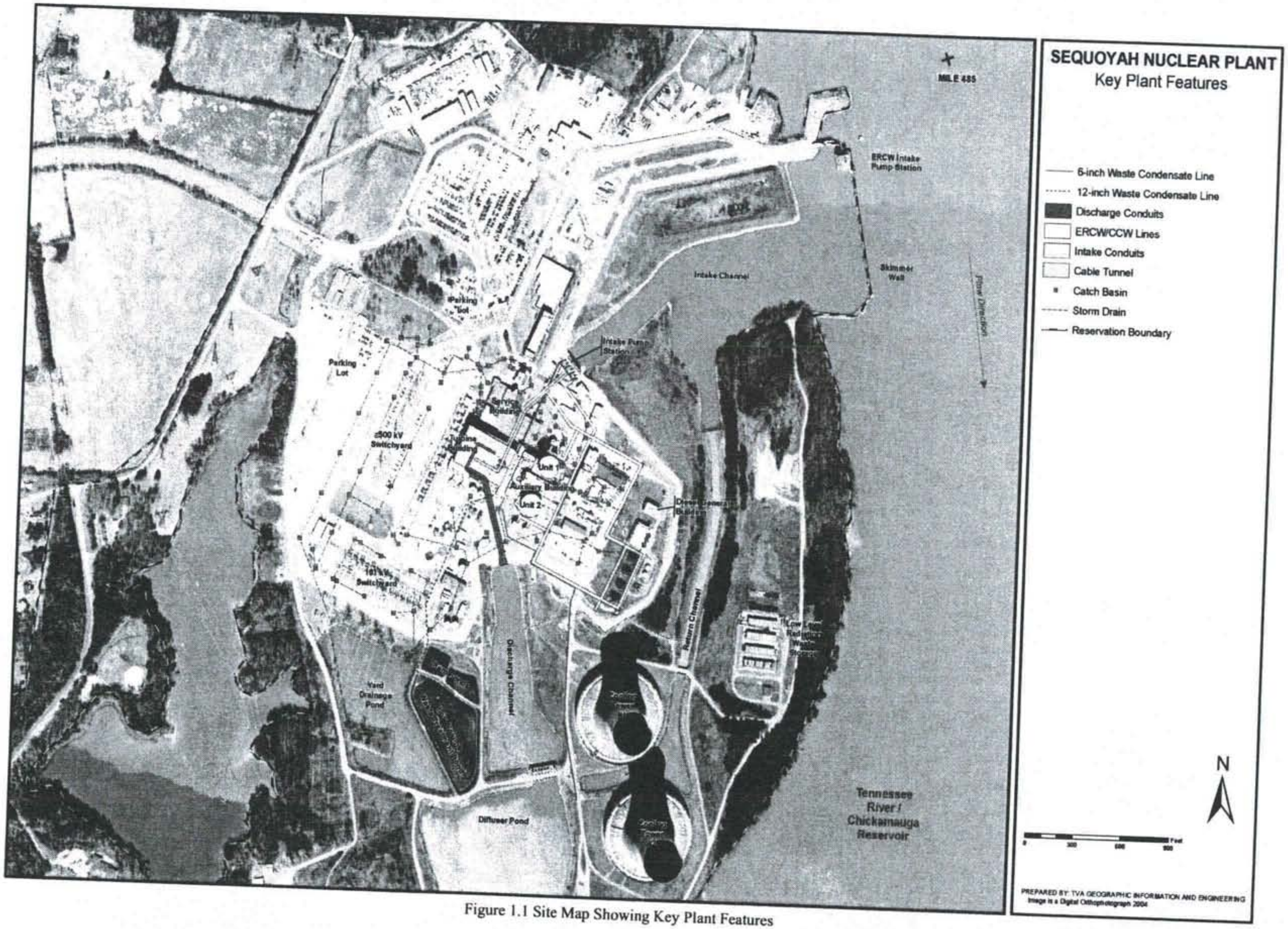


Figure 1.1 Site Map Showing Key Plant Features

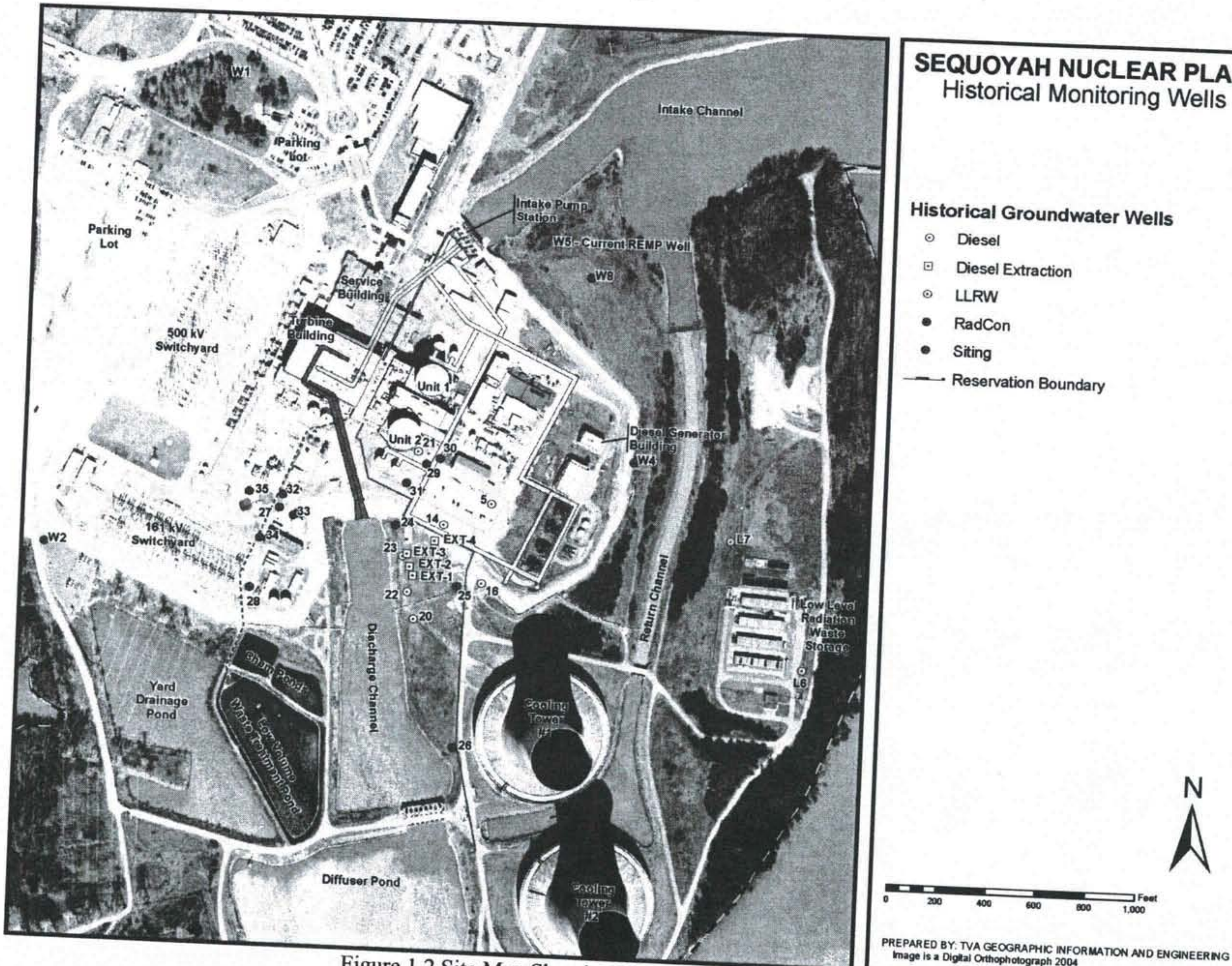


Figure 1.2 Site Map Showing Historical Monitoring Wells

In February 2002, TVA expanded the REMP groundwater monitoring at SQN by installing five additional soil monitoring wells (wells 24 – 28) along 6- and 12-inch diameter condensate pipelines. These lines convey condensate and radwaste effluent from the Turbine and Auxiliary Buildings, respectively (Figure 1.1). The 6- and 12-inch lines discharge into the 72-inch cooling tower blow-down line and Low-Volume Waste Treatment Pond, respectively. Initial samples collected from these wells indicated no evidence of tritium (<220 pCi/L).

Monthly groundwater sampling for tritium was prescribed for well 27 beginning in August 2003. Tritium was consistently observed slightly above the minimum detection concentration (MDC) of 220 pCi/L at this well beginning in September 2003. The consistency of observations prompted a sampling event in January and February 2004 that included other site wells (W14 and W21) in conjunction with manual sampling of vicinity sumps, moats, storm drain catch basins, and ponds. A relatively high tritium concentration of 9,080 pCi/L was observed at well 21. A subsequent set of seven monitoring wells (wells 29 – 35) were installed in April 2004, with routine sampling of selected wells beginning in May 2004. To date, tritium concentrations in these wells have ranged from MDC to 19,750 pCi/L. These concentrations have not exceeded the Environmental Protection Agency (EPA) Drinking Water Standard of 20,000 pCi/l for tritium (40 CFR 141.25). The Nuclear Regulatory Commission (NRC) Site Resident at SQN has been notified and is being kept informed as investigations continue.

2.0 BACKGROUND

2.1 Radiological Environmental Monitoring Program (REMP)

The preoperational environmental monitoring program has established a baseline of data on the distribution of natural and manmade radioactivity in the environment near the plant site. The preoperational environmental monitoring program was initiated in the spring of 1971. The operational monitoring program initiated in the spring of 1980 reflects the current monitoring philosophy and regulatory guidelines.

REMP reports have been prepared by TVA's Western Area Radiological Laboratory (WARL) and SQN personnel since inception of the program in 1971. The SQN REMP has been modified over time to adjust for sampling locations, sampling methods, analytes, reporting frequency, and changes in laboratory methods/instruments and MDCs.

Currently, REMP reports catalog onsite direct radiation sampling, atmospheric radiation monitoring at eight sites located 10 to 20 miles from the plant, terrestrial radiation monitoring at area farms within six miles of the plant, and liquid pathway radiation monitoring along the Tennessee River and from area groundwater wells.

TVA participates in an Interlaboratory Comparison Program. This program provides periodic cross-check samples of the type and radionuclide composition normally analyzed in an environmental monitoring program. Results obtained in the monitoring and the cross-check programs are reported annually to the NRC.

Groundwater and surface water sampling have been a part of the program since it was instituted in 1971, and remain part of the current liquid pathway monitoring program. Onsite and offsite monitoring locations for groundwater and surface water are shown in Figures 2.1 and 2.2, respectively.

2.1.1 REMP Groundwater

The monitoring well network at SQN (Figure 1.2) included six regional monitoring wells (wells W1, W2, W4, W5, and W8) that were installed before 1977. Quarterly groundwater monitoring for tritium began in 1977 at four bedrock monitoring wells (W1, W2, W4, and W5) located along the perimeter of the site (Figure 2.1). Onsite REMP groundwater monitoring was reduced to a single well (W5) in 1981. Offsite groundwater sampling also began in 1977 at seven area farms; but, since 1986 samples have been collected at just one location (Farm HW well; see Figure 2.2).

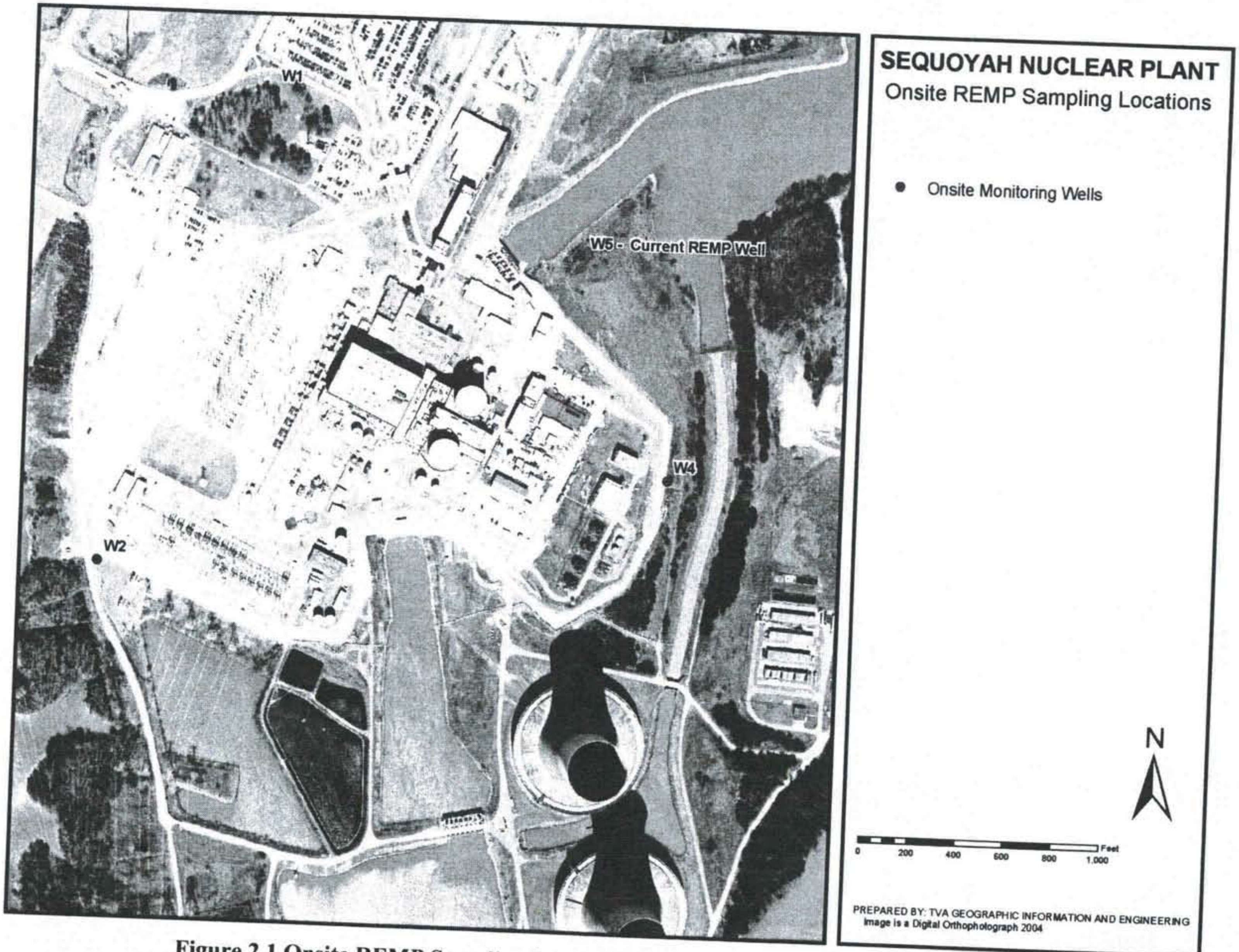


Figure 2.1 Onsite REMP Sampling Locations for Groundwater and Surface Water

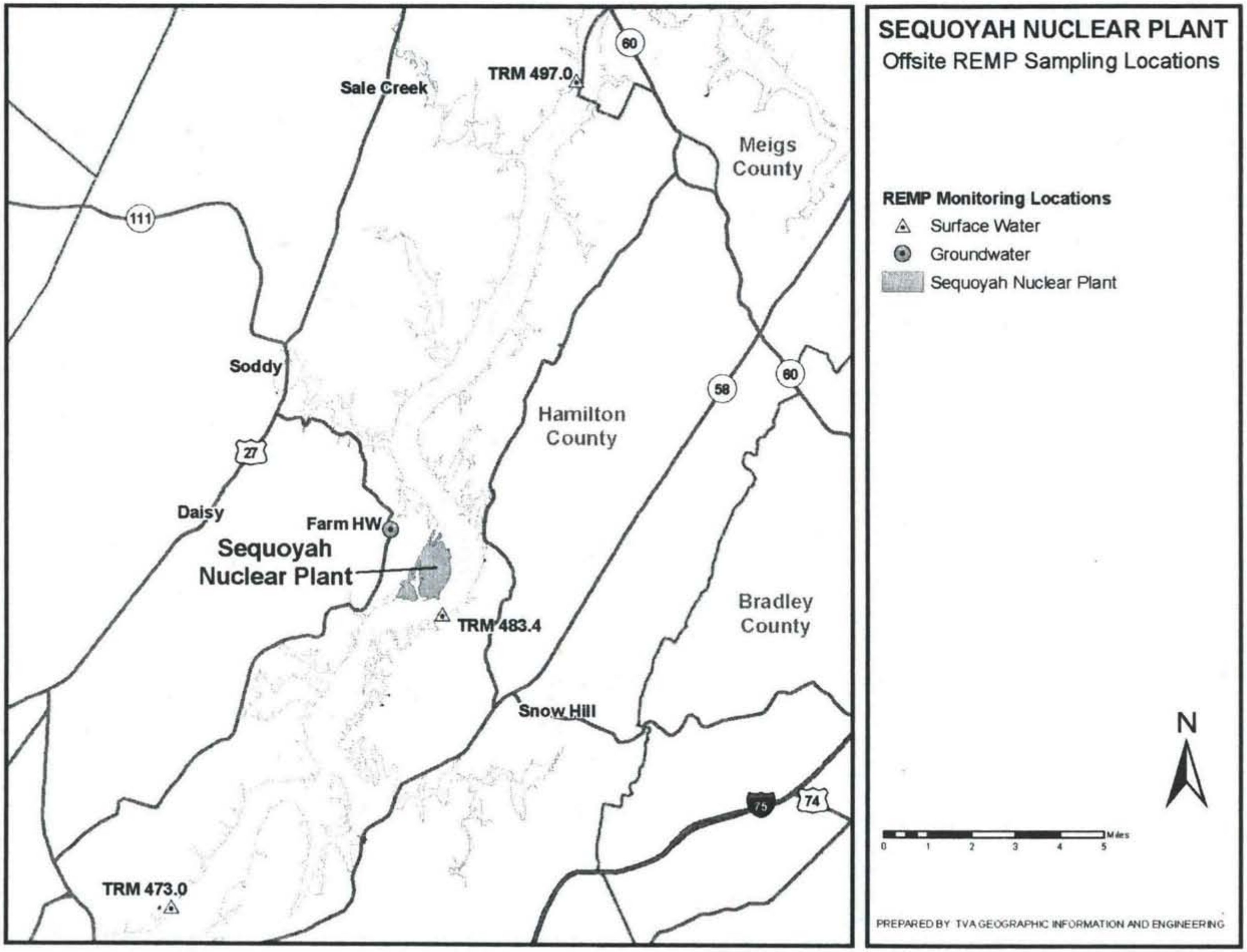


Figure 2.2 Offsite REMP Sampling Locations for Groundwater and Surface Water

In the earlier years, groundwater was collected by grab sampling. Sometime in the late 1970s or early 1980s, well W5 was equipped with an automatic sampler. The automatic sampler transmits a daily sample aliquot to a composite container for monthly retrieval. Manual samples are collected quarterly from the offsite Farm HW well.

Quarterly samples are analyzed by gamma spectroscopy using a one pass method with an intrinsic germanium detector (Vortec and Canberra instruments). Samples are first distilled by centrifuging 50 ml of liquid, distilling that volume (if it is turbid), and then extracting 15ml to be analyzed. The composite sample is analyzed by gamma spectroscopy for gross beta activity (monthly) and tritium analysis is conducted on a quarterly basis. Tritium analysis is completed by liquid scintillation methods using a Packard scintillation unit. A total of five scintillation counts are performed for each test. Results are reported as the mean of the three highest counts.

Results of REMP groundwater monitoring are shown in Figure 2.3. From the period 1977 – 1998, both onsite and offsite groundwater monitoring indicates tritium concentrations that are <MDC or are within the range of expected background concentrations. Tritium was initially observed in SQN groundwater at onsite well W5 from 1989 sampling at a background concentration of 379 pCi/L. No other detection of tritium was observed at well W5 until 1998. However, from 1998 through 2001, tritium was consistently observed at concentrations ranging from 401 to 2,120 pCi/L at well W5. No further tritium detection has been observed at well W5 since 2001. During the period 1998 – 2001, tritium concentrations at the offsite Farm HW well and at all surface water monitoring locations were <MDC (Figure 2.3). Hence, tritium observations at well W5 during the 1998 – 2001 time interval exceed background concentrations and suggest an onsite source of contamination.

2.1.2 REMP Surface Water

Surface water sampling locations have remained constant throughout the REMP program, including one upstream location and two downstream locations (Figure 2.2). The upstream sampling location is the City of Dayton drinking water supply intake station at Tennessee River Mile (TRM) 497.0. The downstream samples are collected at Eastside Utility District water intake (TRM 473.0) and at a temperature station 0.3 mile downstream from the SQN discharge (TRM 483.4).

Samples are collected by automatic ISCO samplers at each of the three locations. The instruments are programmed to accumulate discreet samples every two hours and composite samples are collected monthly. The composite sample is analyzed for gross beta activity (monthly) and tritium (quarterly) using the methods described in Section 2.1.1.

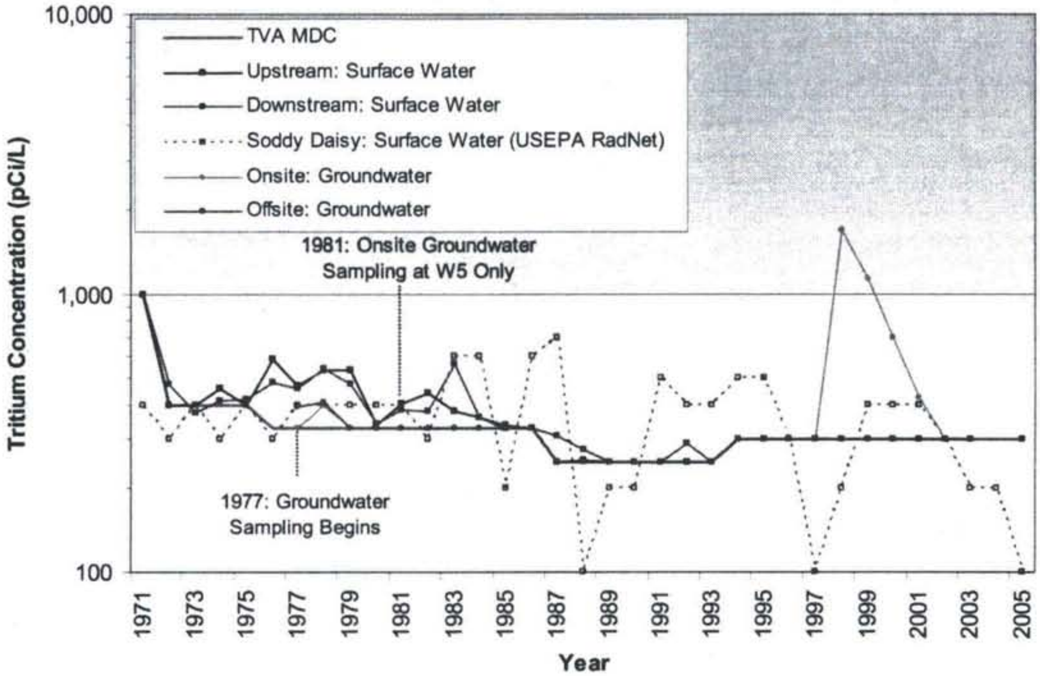


Figure 2.3 Time-Series Tritium Concentrations from REMP Groundwater and Surface Water Monitoring

Results of REMP surface water monitoring are shown in Figure 2.3. For comparison, USEPA RadNet surface water data (USEPA, 2007) for Soddy Daisy, Tennessee are depicted in the figure. The SQN REMP data indicate no evidence of tritium or other radionuclides exceeding detection levels in offsite surface water or groundwater samples since 1992. Pre-1992 tritium concentrations in surface water samples reflect ambient concentrations resulting most probably from cosmogenic sources and nuclear weapons testing from the 1940s through the 1970s.

2.2 Radwaste System

2.2.1 Liquid Radwaste System

Liquid, gaseous, and solid radwaste disposal facilities at SQN are designed so that discharges of effluents are in accordance with 10 CFR Parts 20 and 50. The Liquid Waste Processing System is designed to receive, segregate, process, recycle for further processing, and discharge liquid wastes. Liquids entering the Liquid Waste Processing System are collected in sumps and tanks until determination of subsequent treatment can be made. They are sampled and analyzed to quantify radioactivity, with an isotopic accounting if necessary. Processed radioactive wastes not suitable for reuse and the liquid waste suitable for reuse, whose volume is not needed for plant operations or not desired for reuse, are discharged from the plant or packaged for offsite disposal. Design and operation of the Radwaste System is characteristically directed toward minimizing releases to unrestricted areas. Under normal plant operation, the activity from radionuclides leaving the discharge canal is a small fraction of the limits in 10 CFR Parts 20 and 50.

2.2.1.1 System Descriptions

The Liquid Waste Processing System was initially designed to collect and process potentially radioactive wastes for recycle to the Reactor Coolant System or for release to the environment. The liquid waste processing system was, by original design, arranged to recycle as much reactor-grade water entering the system as practical. This was implemented by the segregation of equipment drains and waste streams, which prevents the intermixing of liquid wastes. The layout of the liquid waste processing system, therefore, consists of two main subsystems designed for collecting and processing reactor-grade (tritiated) and non-reactor-grade (non-tritiated) water, respectively. All liquids are now routinely processed as necessary for release to the environment instead of recycling, and are no longer maintained segregated based on tritium content during processing. This includes reprocessing the contents of tanks which accumulate waste water for discharge which may be unsuitable for direct release. Provisions are made to sample and analyze fluids before they are discharged. Based on the laboratory analysis, these wastes are either released under controlled conditions via the cooling water system or retained for further processing. A permanent record of liquid releases is provided by analyses of known volumes of waste. Actual radionuclide inventories of plant effluents are submitted to the NRC as a requirement of 10 CFR 50 by Nuclear Chemistry Offsite Dose Calculation Manual (ODCM).

In addition, a system is provided for handling laboratory samples which may be tritiated and may contain chemicals. Capability for handling and storage of spent demineralizer resins is also provided.

The plant system is controlled from a central panel in the Auxiliary Building and a panel in the main control room. All system equipment is located in or near the Auxiliary Building, except for the reactor coolant drain tank and drain tank pumps and the various Reactor Building floor and equipment drain sumps and pumps which are located in the Containment Building.

The Radwaste Demineralizer System (Rad DI) is located and operated in the Auxiliary Building railroad access bay when the vendor's service is requested.

At least two valves must be manually opened to permit discharge of liquid to the environment. One of these valves is normally locked closed. A control valve trips closed on a high effluent radioactivity level signal. Controls are provided to prevent discharge without dilutions.

2.2.1.2 Shared Components

Parts of the Liquid Waste Processing System are shared by the two units. The Liquid Waste Processing System consists of one reactor coolant drain tank with two pumps, an Auxiliary Reactor Building floor and equipment drain sump with two pumps, a keyway sump with one pump, and a Reactor Building floor and equipment drain sump with two pumps inside the Containment Building of each unit. It also includes the following shared equipment located inside the Auxiliary Building: one sump tank and two pumps; one tritiated drain collector tank with two pumps and one filter; one floor drain collector tank with two pumps and one strainer; a monitor tank and two pumps; a chemical drain tank and pump; two hot shower tanks and pump; a spent resin storage tank; a cask decontamination tank with two pumps and two filters; the Auxiliary Building floor and equipment drain sump and two pumps; a passive sump; a Radwaste Demineralizer System; and the associated piping, valves, and instrumentation.

The following shared components are located in the Condensate Demineralizer Building for receiving, processing, and transferring wastes from the regeneration of condensate demineralizers: high crud, low conductivity tanks, pumps, and filters; a neutralizer tank and pumps; and a non-reclaimable waste tank and pumps.

2.2.1.3 Separation of Tritiated and Nontritiated Liquids

Waste liquids that are high in tritium content are routed to the tritiated drain collector tank; while liquids low in tritium content are routed to the floor drain collector tank. All tritiated and nontritiated liquid waste are processed for discharge to the environment.

2.2.1.4 Tritiated Water Processing

Tritiated reactor grade water is processed for discharge to the environment or for recycle to the primary water storage tank. The water enters the liquid waste disposal system from equipment leaks and drains, valve leakage, pump seal leakage, tank overflows, and other tritiated and aerated water sources including draining of the Chemical and Volume Control System (CVCS) holdup tanks, as desired.

The equipment provided in this channel consists of a tritiated drain collector tank, pumps, and filter and Radwaste Demineralizer System. The primary function of the tritiated drain collector tank is to provide sufficient surge capacity for the radwaste processing equipment.

The liquid collected in the tritiated drain collector tank contains boric acid, and fission product activity. The liquid can be processed as necessary to remove fission products so that the water may be reused in the Reactor Coolant System or discharged to the environment.

2.2.1.5 Nontritiated Water Processing

Nontritiated water is sampled and processed as necessary for discharge to the river. The sources include floor drains, equipment drains containing nontritiated water, certain sample room and radiochemical laboratory drains, hot shower drains and other nontritiated sources. The equipment provided in this channel consists of a floor drain collector tank, pumps, and strainer, Radwaste Demineralizer System, hot shower tanks and pump, cask decontamination collector tank and pumps, and monitor tank and pumps.

Liquids entering the floor drain collector tank are from small volume, low activity sources. If the activity is below permissible discharge levels following analysis to confirm acceptably low level, then the tank contents may be discharged without further treatment other than filtration. Otherwise, the tank contents are processed through the Radwaste Demineralizer System.

The hot shower drain tanks normally need no treatment for removal of radioactivity. The inventory of these tanks may be discharged directly to the cooling tower blowdown via the hot shower tank strainer or to other tanks in the liquid waste system.

The liquid waste system is also designed to process blowdown liquid from the steam generators of a unit having primary-to-secondary leak coincident with significant fuel rod clad defects. The blowdown from the steam generators is passed through the condensate demineralizer or directly to the cooling tower blowdown line.

2.2.1.6 Releases of Liquid Radwaste

The Tennessee River/Chickamauga Lake is the sole surface water pathway between SQN and surface water users along the river. Liquid effluent from SQN flows into the river from a diffuser pond through a system of diffuser pipes located at TRM 483.65. The contents of the diffuser pond enter the diffuser pipes and mix with the river flow upon discharge. The diffusers are designed to provide rapid mixing of the discharged effluent with the river flow. The flow through the diffusers is driven by the elevation head difference between the diffuser pond and the river. Flow into the diffuser pond occurs via the blowdown line, Essential Raw Cooling Water (ERCW) System, and Condenser Circulating Water (CCW) System. Two parallel pipelines comprise the diffuser system which is designed to provide mixing across nearly the entire width of the main channel.

Release of radioactive liquid from the Liquid Waste Processing System can be from the cask decontamination collector tank, CVCS monitor tank, hot shower tanks, or chemical drain tank to the cooling towers blowdown line via the 6-inch diameter Waste Condensate Line (Figure 1.1). The cooling tower blowdown line empties into the diffuser pond which discharges into the river through the diffuser pipes. Liquid wastes from the condensate Demineralizer system are released from the high crud low conductivity tanks, the non-reclaimable waste tank, and the neutralization tank.

The CCW system operates in three modes: open, closed, and helper. In the open mode, the cooling towers are not used. Cooling water is pumped from the intake and through the condenser, and is discharged into the diffuser pond. Dilution water for the radioactive liquid is provided by ERCW, which is in continuous operation and discharges to the cooling tower cold water canal. A weir at Gate Structure 1 ensures that under most river level conditions, the ERCW flow is diverted through the cooling tower blowdown line. The radioactive liquid is mixed with ERCW in the cooling tower blowdown line and flows into the diffuser pond.

In the closed mode, CCW is recirculated between the cooling towers and the condenser. In this mode of operation, the cooling towers blowdown flows at a minimum of 150,000 gpm into the diffuser pond in order to maintain the solids in the cooling water at an acceptable level.

In the helper mode, the CCW from the condenser goes through the cooling towers and is released to the diffuser pond through Gate Structure 1 and the cooling tower blowdown line.

Release of the radioactive liquids from the liquid waste system is made only after laboratory analysis of the tank contents. Once the fluids are sampled, they are pumped to the discharge pipe through a remotely operated control valve, interlocked with a radiation monitor and with instrumentation to ensure adequate dilution flow in the cooling tower blowdown line.

Minimum dilution flow can also be determined via ERCW flow instrumentation, or by periodic flow rate estimation. A similar arrangement is provided for wastes discharged from the condensate demineralizer waste system. The flow control valve is interlocked with a radiation monitor. Release of wastes will be automatically stopped by a high radiation signal.

The steam generator blowdown system may discharge radioactive liquid. Liquid waste from this system is not collected in tanks for treatment, but is continuously monitored for radioactivity and may discharge to the cooling tower blowdown, or recirculate to the condensate system upstream of the condensate demineralizers. The flow control valve in the discharge line is interlocked with a radiation monitor and with instrumentation to ensure adequate dilution flow on the cooling tower blowdown. Minimum dilution flow can also be determined via ERCW flow instrumentation, or by periodic flow rate estimation.

The Turbine Building sump collects liquid entering the Turbine Building floor drain system or from clean water sources in the Auxiliary Building that are transferred to the Turbine Building sump. When the sump is nearly full (maximum capacity 30,000 gallons), the liquid is automatically discharged (level initiated) to the Low-Volume Waste Treatment Pond or the Yard Drainage Pond via the 12-inch diameter Waste Condensate Line (Figure 1.1). The Yard Drainage Pond drains by gravity to the Diffuser Pond which ultimately discharges to the river via the diffusers.

Means are provided for radiological monitoring during normal operations, including anticipated operational occurrences, and during accident condition various process streams and gaseous and liquid effluent discharge paths. Some of the monitors initiate automatic control actions. Continuous radiological monitoring instruments for liquid processes and effluents include the following locations.

1. Station Sump Discharge Monitor (Turbine Building)
2. Waste Disposal System Discharge Monitor (Auxiliary Building)
3. ERCW Discharge Monitor (Headers A & B)
4. Condensate Liquid Demineralizer Monitor (Demineralizer Building)
5. Steam Generator Blowdown Liquid Discharge Monitor (Turbine Building)
6. Component Cooling System Monitor (Auxiliary Building)

The release locations are also subject to periodic sampling and include all liquid releases which could exceed the limits given in Appendix I, 10 CFR 50 and 10 CFR 20. The sampling and analysis requirements for these release points are defined in the SQN ODCM controls. The plant discharge meets Regulatory Guide 1.21 Revision 1, 10 CFR 20, and 10 CFR 50 guidelines.

The offsite dose calculations for drinking water are based on the assumption that the liquid effluent will be mixed with 60 percent of the river flow between the point of discharge and Chickamauga Dam. Although further mixing will occur, 60 percent dilution is assumed to be maintained for approximately 14 miles until Chickamauga Dam (TRM 471.0) is reached where 100 percent dilution is assumed to occur.

2.2.2 Waste Condensate Lines

Figure 1.1 shows the locations of the 6- and 12-inch waste condensate lines at the site. The 12-inch waste condensate line receives water from the Turbine Building sump. Turbine Building drains are collected in the Turbine Building sump or discharged directly to various ponds or CCW discharge. Non-radioactive raw cooling water booster pump skid drains, SGB sample panel drains, and auxiliary feedwater pump leakoff drains are also collected in the Turbine Building sump. A temporary-use manifold allows RADCON-approval drainage (e.g., Cycle Outage Ice Melt) to be discharged to the Turbine Building sump. The header penetrates the Auxiliary/Turbine Building wall connecting to an existing drain (old titration room drain) and travels by gravity to the sump.

High conductivity chemical regenerate and rinse wastes that are produced during condensate demineralizer regeneration are routed to the neutralization tank (NT) or, alternately, to the nonreclaimable waste tank (NRWT) where they are collected and neutralized. If the contents of either tank (NT or NRWT) are not radioactive or if the radioactivity level is less than the discharge limit, it is transferred to the Turbine Building sump and subsequently discharged through the low volume waste treatment pond, or alternately it is discharged to the cooling tower blowdown via the 6-inch waste condensate line. If the contents of either the NT or NRWT are radioactive, they may be discharged to the cooling tower blowdown if the radioactivity level is within specification; otherwise, they are processed by the radwaste system.

The Turbine Building sump level is controlled by a high-low level switch that energizes the sump pumps. The sump effluents can be routed to the Yard Drainage Pond or the Low Volume Waste Treatment Pond.

The 6-inch waste condensate line receives routine (almost daily) radioactive effluent discharges from the Liquid Waste Processing System described in preceding sections. Potential leakage of this line was identified as a potential tritium source based on comparable tritium investigations completed at Watts Bar Nuclear Plant (WBN; ARCADIS, 2004), and similarity of SQN plant design to WBN.

The operating pressure of the 6-inch waste condensate line during a radwaste release varies from about 4 psig to negative pressure. Pressure testing of the 6-inch waste condensate line was performed under SQN work order no. 04-776838-004 on April 7, 2006. Service air was used to pressurize the line to 50 psig. After approximately 24 hours, the pressure was measured at 49 psig. After 70 hours the pressure was measured at 47 psig.

On July 10, 2006 a leakage test was performed by connecting a hose from the Demineralizer Water System to the waste condensate line and filling the pipeline. Following the initial fill, a rotometer was installed (range 0 – 120 cc/min). Experimentation with the rotometer indicated that the lower detection limit of flow was about 1 drop per second which corresponds to approximately 1.3E-05 gpm.

Flow was allowed to stabilize for three weeks. After this period and on two separate occasions, the water supply was isolated (valve closure) from the condensate line. After four days of isolation, the water supply valve was reopened. On each occasion, the ball in the rotometer was observed to have zero movement as the water supply valve was opened. Pressure gauge readings were obtained to ensure that the rotometer results were not invalidated by temperature changes in the condensate line. Results indicated that rotometer testing was valid. The test pressure was approximately 40 psig. Therefore, a leak was not observed at the detection limit of the rotometer and conclusions by SQN staff were that the line does not leak.

2.2.3 Gaseous Radwaste System

Controlled airborne releases from the plant ventilation system may result in measurable atmospheric deposition of plant-related radionuclides (including tritium) in the vicinity of the site. Some of this material may accumulate on plant roof surfaces and discharge into roof drains during precipitation events. Rain may also wash airborne releases onto facility soil and building surfaces.

The impact of this potential source of groundwater contamination may vary substantially with release periods and meteorological conditions. While this potential source is not likely to be a major contributor to groundwater contamination, operators of at least one nuclear power plant believe that measurable tritium concentrations in groundwater at their site are likely due to the deposition of tritium in airborne effluents (NRC, 2006). Recognition that atmospheric deposition may be a process actively contributing to observed wide-spread, low-level tritium concentrations in groundwater would allow explanation of the presence of these low-level concentrations when no other potential source can be identified.

The Gaseous Waste Processing System is designed to remove fission product gases from the reactor coolant and to permit operation with periodic discharges of small quantities of fission gases through the monitored plant vent. This is accomplished by internal recirculation of radioactive gases and holdup in the nine gas decay tanks to reduce the concentration of radioisotopes in the released gases. The offsite exposure to individuals from gaseous effluents released during normal operation of the plant is limited by Appendix I of 10 CFR 50 and by 40 CFR 190.

The Gaseous Waste Processing System consists of two waste-gas compressor packages, nine gas decay tanks, and the associated piping, valves and instrumentation. The equipment serves both units. Gaseous wastes can be received from the following: degassing of the reactor coolant and purging of the volume control tank prior to a cold shutdown, displacing of cover gases caused by liquid accumulation in the tanks connected to the vent header, purging of some equipment, sampling and gas analyzer operation, and boron recycle process operation (no longer in service).

Gaseous radioactive wastes are released to the atmosphere through vents located on the Shield Building, Auxiliary Building, Turbine Building, and Service Building.

2.3 Inadvertent Releases of Liquid Radwaste

Design and operation of the Radwaste System is characteristically directed toward minimizing releases to unrestricted areas. However, accidental releases of radioactive effluents and unusual occurrences to outdoor environs at SQN have been documented by TVA (2006) for the period from July 1981 (Unit 1 startup) to July 2006. A comprehensive review of these data is important for this investigation since these historical releases may serve as sources of tritium identified within the site groundwater system. Records of releases by TVA (2006) are based on report documentation for most of the occurrences and via interviews conducted with SQN Radiation Protection staff for earlier events.

Eight accidental releases of radioactive effluents and unusual occurrences to outdoor environs at SQN have been documented to date. Figure 2.4 identifies the approximate locations of these events and descriptions are provided in the following paragraphs.

1. *Condensate Demineralizor Waste Evaporator (CDWE) Building – mid-1980s*

   Based on personnel interviews, radioactivity leached through a concrete wall of the CDWE Building to an outside concrete slab and soil. It is presumed that this was an aqueous release. Contaminated soil was excavated and the building wall was painted with sealant. Quarterly surveys (RMD-FO-35) were subsequently performed by Radiation Protection.

2. *Unit 2 Additional Equipment Building (Upper Head Injection) – mid-1980s*

   Based on personnel interviews, a hose burst spraying water through a door to outside environs. An asphalt area was painted with sealant, and a vehicle and Porta-John toilet were decontaminated. Quarterly surveys (RMD-FO-35) were subsequently performed by Radiation Protection.

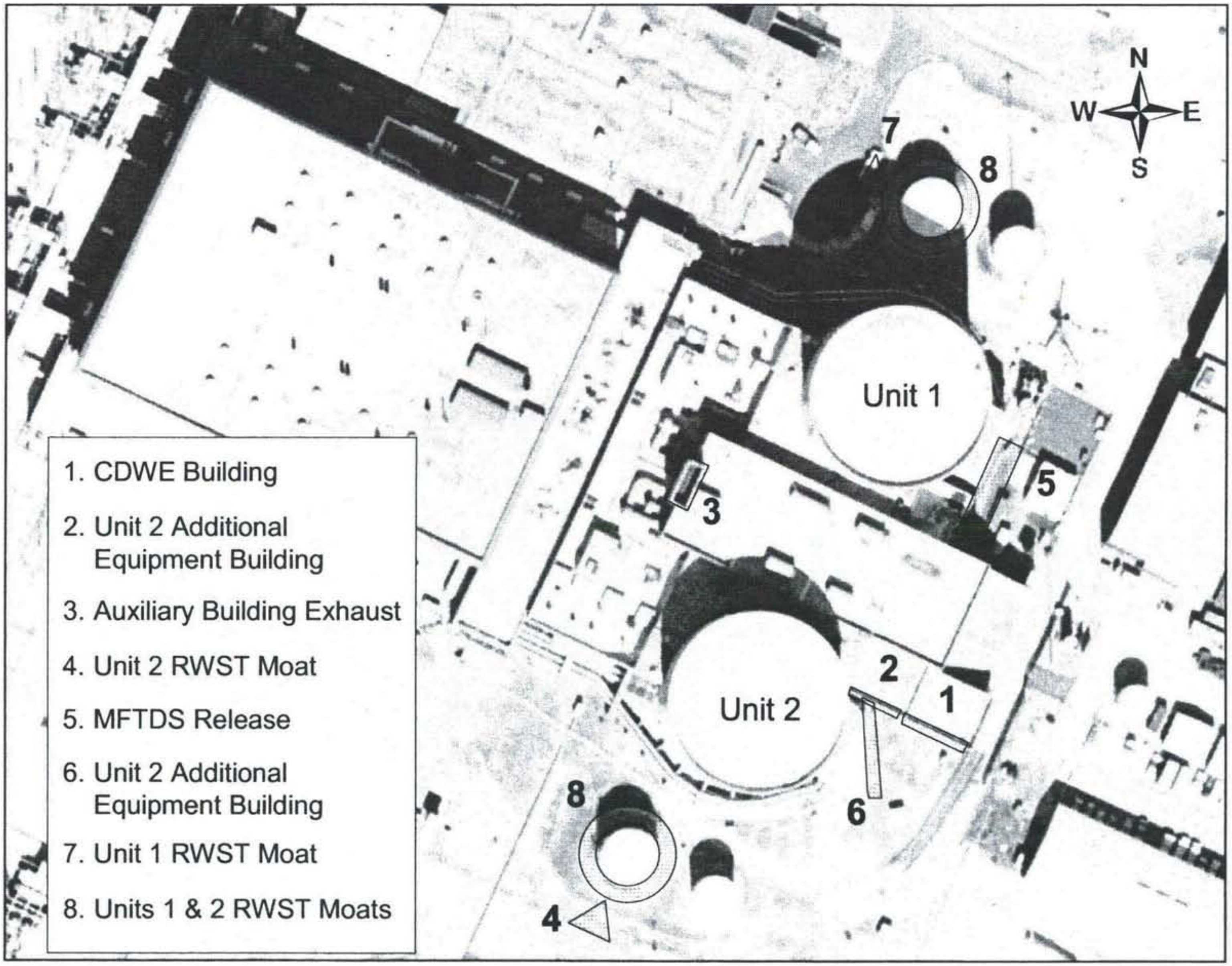


Figure 2.4 Site Map Showing Locations of Inadvertent Releases of Liquid RadWaste

3. *Auxiliary Building Roof – early 1990s*

Based on personnel interviews, radioactive contamination was discovered on the Auxiliary Building roof. Origin of contamination was determined to be unfiltered fuel handling ventilation trains associated with Auxiliary Building ventilation stack discharge. Remediation is cited as contamination being removed from the roof. Quarterly surveys (RMD-FO-35) were subsequently performed by Radiation Protection.

4. *Unit 2 Refueling Water Storage Tank (RWST) Moat Drain – May 10, 1995*

During performance of a routine environmental monitoring survey (RMD-FO-35), radioactivity was identified in soil at the moat drainage outlet of the Unit 2 RWST (Figure 2.5). The drain outlet is located on the south side of the moat and discharges to gravel covered soil. Follow-up sampling was performed and Co-58, Co-60, Cs-134, and Cs-137 were identified in soil in excess of the MDC of 5.0E-07 μCi/g. Documentation includes survey number D-95-0558 with attached sample gamma analysis results from WARL.

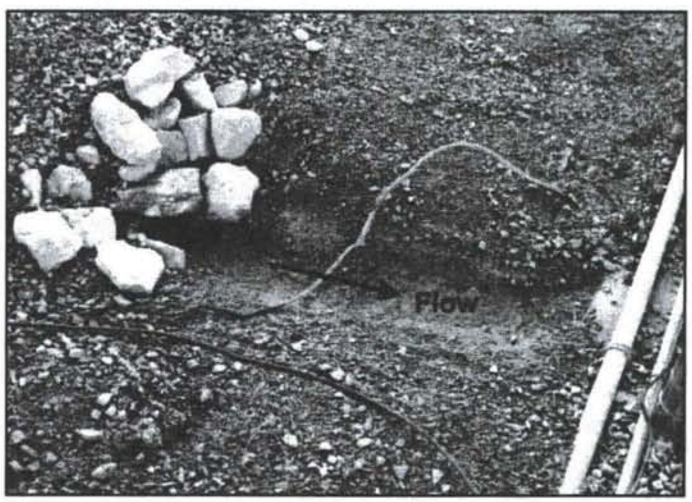


Figure 2.5 Photograph of Unit 2 Moat Drainage to Ground Surface

5. *Modularized Transfer Demineralization System (MFTDS) Release to Railroad Bay – May 19, 1997*

Due to failure of the conductivity probe on the MFTDS, approximately 3,000 gallons of water was released to the 706 ft-msl elevation Railroad Bay (Figure 2.6). It was estimated that 600-1000 gallons of water was released to the RadWaste Yard immediately adjacent to the Railroad Bay door. Problem Evaluation Report (PER) No. SQ971429PER was initiated to investigate the release. A subsequent report (Smith, 1997) addresses cleanup at the site.

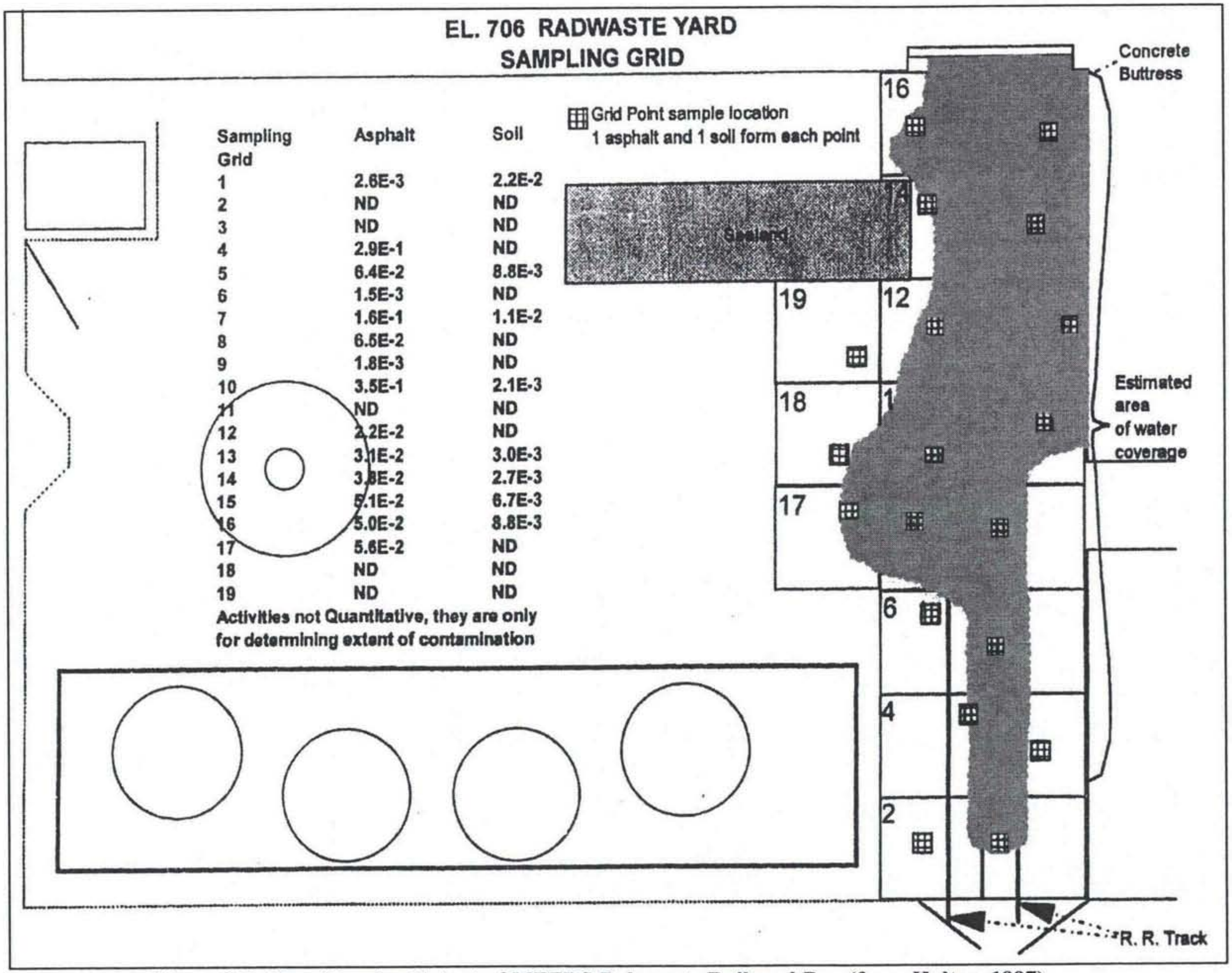


Figure 2.6 Map Showing Extent of MFTDS Release to Railroad Bay (from Halter, 1997)

Smith (1997) indicates that the water spill was observed to spread over a 950 ft^2 asphalted area. The initial response also noted a vortex near railroad ties within the release area. Subsequent investigation revealed a French drain system parallel to both sides of the existing railroad track and extending outside of the Radiation Control Area (RCA). Soils samples were collected and select isotopes (Co-57, Co-58, Co-60, Cs-134, Cs-137, Nb-95, and Mn-54) were screened to 5.0E-07 μCi/g. Results indicated radioactive contamination at and below the French drain system for several soil samples.

Asphalt and soil were excavated beginning June 6, 1997. Approximately 200 ft^3 of uncontaminated asphalt and 2000 ft^3 of uncontaminated soil were removed outside of the RCA. About 1000 ft^3 of contaminated soil, sand, and gravel were also excavated outside of the RCA. Smith (1997) notes that there were no attempts to remove concrete containing electrical conduit banks that were observed to be contaminated. There were also culverts observed with inaccessible contaminated sand that were not removed. The excavated French drain outside of the RCA was backfilled with concrete.

Excavation of the affected are inside of the RCA resulted in about 5500 ft^3 of radioactive contaminated asphalt, soil, sand, and gravel. The excavation area was 18 x 54 ft with excavation depth being limited by a concrete pad about 3-ft below ground surface. This and other concrete supports within the RCA were not disturbed and residual radioactive is accounted for in Smith (1997). The excavated area within the RCA was backfilled with concrete.

Quarterly surveys (RMD-FO-35) were subsequently performed by Radiation Protection.

6. *Unit 2 Additional Equipment Building (Upper Head Injection) Sump Release – January 10, 1998*

The Unit 2 Additional Equipment Building sump overflowed, exited the double-doors, and continued along a straight-line route (110 linear ft) to the nearest storm drain catch basin (Figure 2.7). The response team observed released water flowing into the catch basin. Sampling confirmed radioactivity in asphalt and soil leading to the catch basin. Water samples collected at the catch basin and at the storm drain discharge to the Yard Drainage Pond did not identify the presence of radioactivity. A water sample collected inside the building indicated Xe-133 to be the dominant radionuclide. A total of 32 soil samples were collected before and during excavation and sample analyses included a peak search for the Xe-133 energy peak. All results were negative. Select isotopes (Co-58, Co-60, Cs-134, and Cs-137) were also used to screen soil samples to 5.0E-07 μCi/g during excavation. Sediment samples from the release area catch basin contained C0-60 and Co-58 at 8.65E-07 and 5.99E-07 μCi/g, respectively.

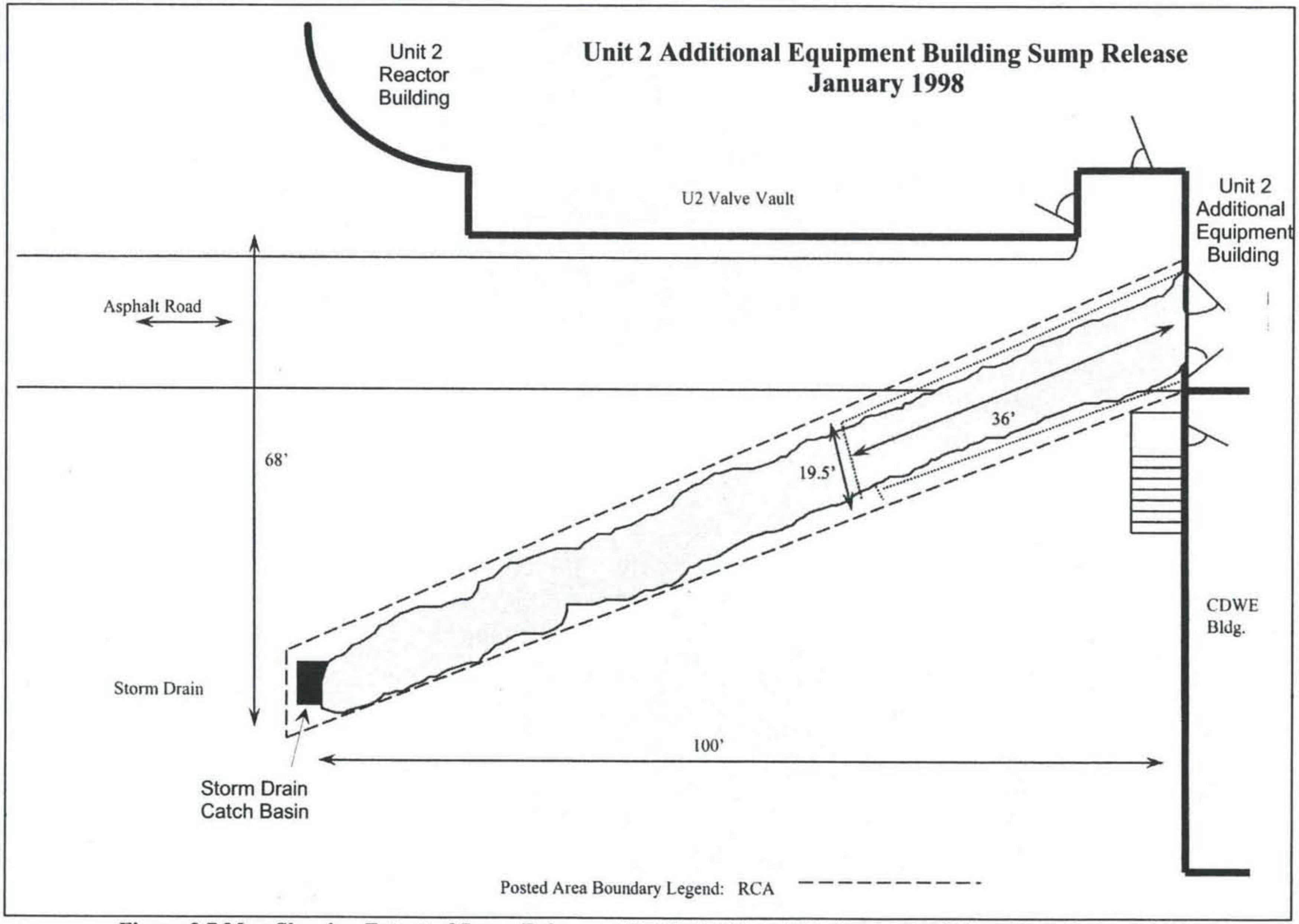


Figure 2.7 Map Showing Extent of Sump Release at Unit 2 Additional Equipment Building (from Halter, 1998)

A recovery report by Halter (1998) described remediation associated with this release. Decontamination of the Additional Equipment Building was initiated on January 10, 1998. Three additional storm drain catch basins were identified for sampling no gamma energy peaks were identified from gamma spectroscopy analyses. The asphalt layer immediately outside of the door was removed. Excavation of gravel and soil along the release route varied from 4 to 10 inches in depth and averaged about 19.5 ft in width. A total of 2070 ft^3 of excavated material was removed and replaced with aggregate material. Figure 2.8 provides photographs of the recovery area. As shown in this figure, groundwater monitoring well W21 is located within the drainage route of the released water.

Quarterly surveys (RMD-FO-35) were subsequently performed by Radiation Protection.

7. *Unit 1 Refueling Water Storage Tank (RWST) Moat Drain – April 3, 2002*

Pre-excavation samples of the steam generator replacement crane foundation identified radioactivity in soil surrounding the Unit 1 RWST moat drain. The drain outlet is located on the west side of the moat, extending through a retaining wall and discharging to an asphalt parking area (Figure 2.9). Soil sampling was performed and radioactivity (Mn-54, C0-57, Co-58, Co-60, SB-125, Cs-134, and Cs-137) was identified in eleven shallow soil samples in excess of the MDCs. Seventeen additional soil samples were collected in August 2002 gamma scans indicated no activity for all samples. Documentation includes a drawing of sample locations with attached sample gamma analysis results from WARL.

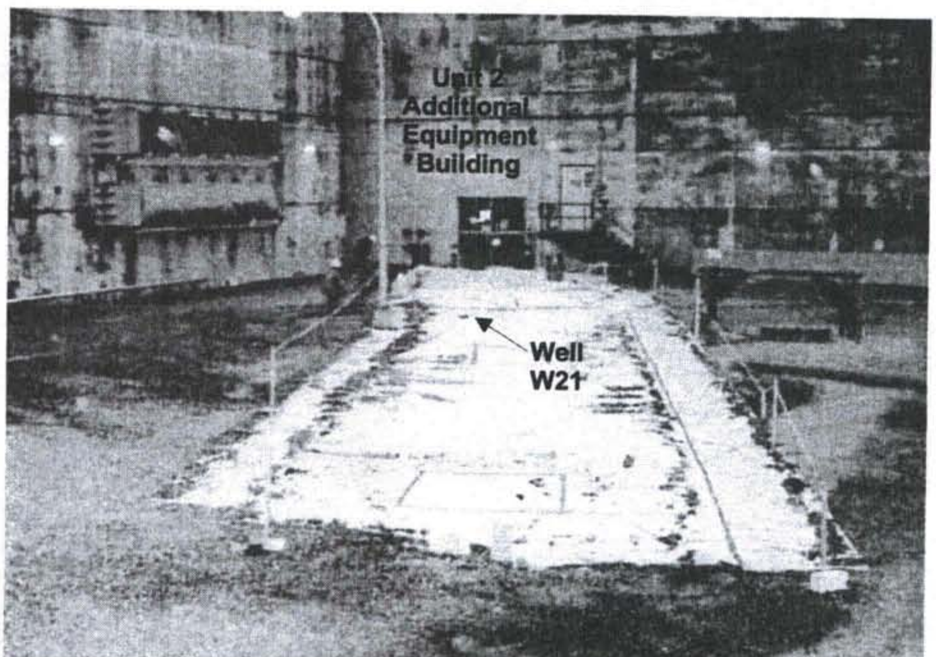
Quarterly surveys (RMD-FO-35) were subsequently performed by Radiation Protection.

8. *Tritium in Unit 1 and 2 RWST Moat Collected Rainwater – July 17, 2006*

Each of the Unit 1 and 2 RWST moats is open to the collection of rainfall. This design differs from other plants such as WBN where permanent covers are installed to direct precipitation away from the moats. Per team discussions at the onset of this investigation, chemistry surveillance instruction 0-SI-CEM-040-421.0 was revised during the first quarter of 2006 to require tritium analysis of moat water. This revision also includes a requirement for discharge of Unit 2 moat water to either the Auxiliary Building RadWaste System or the Turbine Building Sump.

RWST moat water samples were collected July 11, 2006 and tritium concentrations of 517 and 19.5 pCi/mL were observed for Units 1 and 2, respectively. Documentation includes a memorandum by Halter (2006) describing operations, sampling, tritium results, and photographs.

Excavated Area



Release Area Covered with Plastic

Figure 2.8 Photographs of Sump Release Area at Unit 2 Additional Equipment Building (from Halter, 1998)

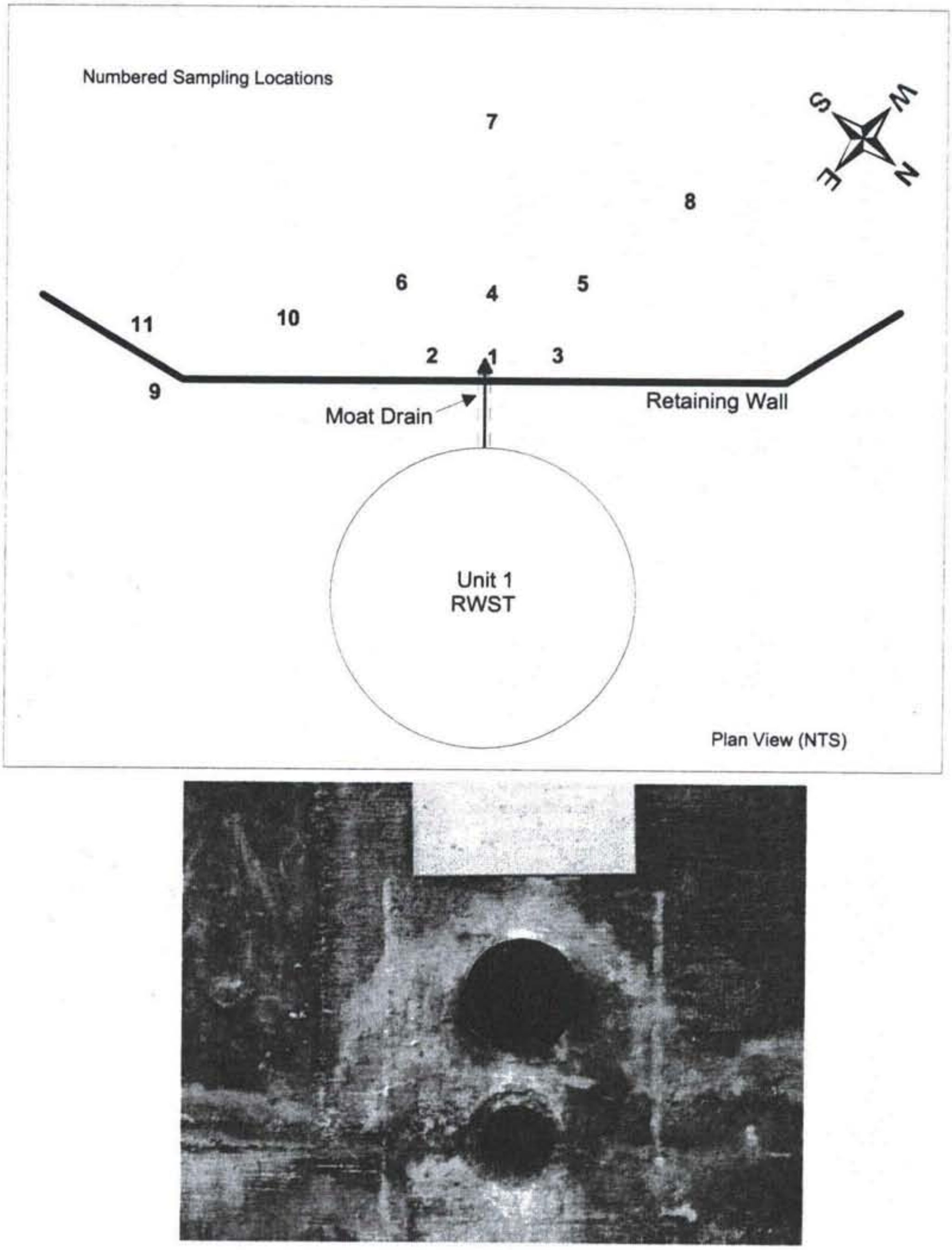


Figure 2.9 Schematic of Sampling Locations and Photograph of Unit 1 RWST Moat Drain

3.0 HYDROGEOLOGY

3.1 Site Location and Scope of Exploration

The SQN site is situated on a peninsula extending from the western bank into Chickamauga Lake between TRM 484 and 485 (Figure 3.1).

Pre-operational subsurface investigations of the site began in 1953. Figure 3.2 depicts the locations of exploratory borings installed at the site during these investigations. Twenty-nine holes were drilled into rock while seventeen were fishtailed to the top of sound rock. From September 1968 to February 1969, additional holes were drilled to fill in a 100-foot grid in the Control and Auxiliary Building area, and in the reactor areas, with holes drilled at the intake structure and other locations in the general plant area. In addition to obtaining information on the foundation conditions, the holes in the reactor areas were used for dynamic seismic investigations. During September and October 1969, a third drilling program was carried out to further investigate the reactor, control, and auxiliary areas on a 50-foot spacing, and to examine the condition of the Kingston fault northwest of the plant site (TVA, 2005).

Post-operational subsurface investigations at the site have been conducted to resolve contaminant release issues and for siting of new facilities. Edwards et al. (1993) and Julian (1993) installed 21 soil borings and 9 groundwater monitoring wells to assess No. 2 Diesel Fuel Oil contamination from underground transfer lines. Julian (2000) conducted a groundwater supply study that included review of groundwater supply wells located in the vicinity of SQN. Siting for the Independent Spent Fuel Storage Installation (TVA, November 2001) involved the installation of three monitoring wells and numerous shallow borings to assess petroleum contamination (TVA, June and September 2001). From February 2002 – April 2004, 12 shallow groundwater monitoring wells were installed for evaluations of tritium releases from the 6- and 12-inch waste condensate lines.

Soil borings and wells installed as part of this tritium investigation are described in following paragraphs.

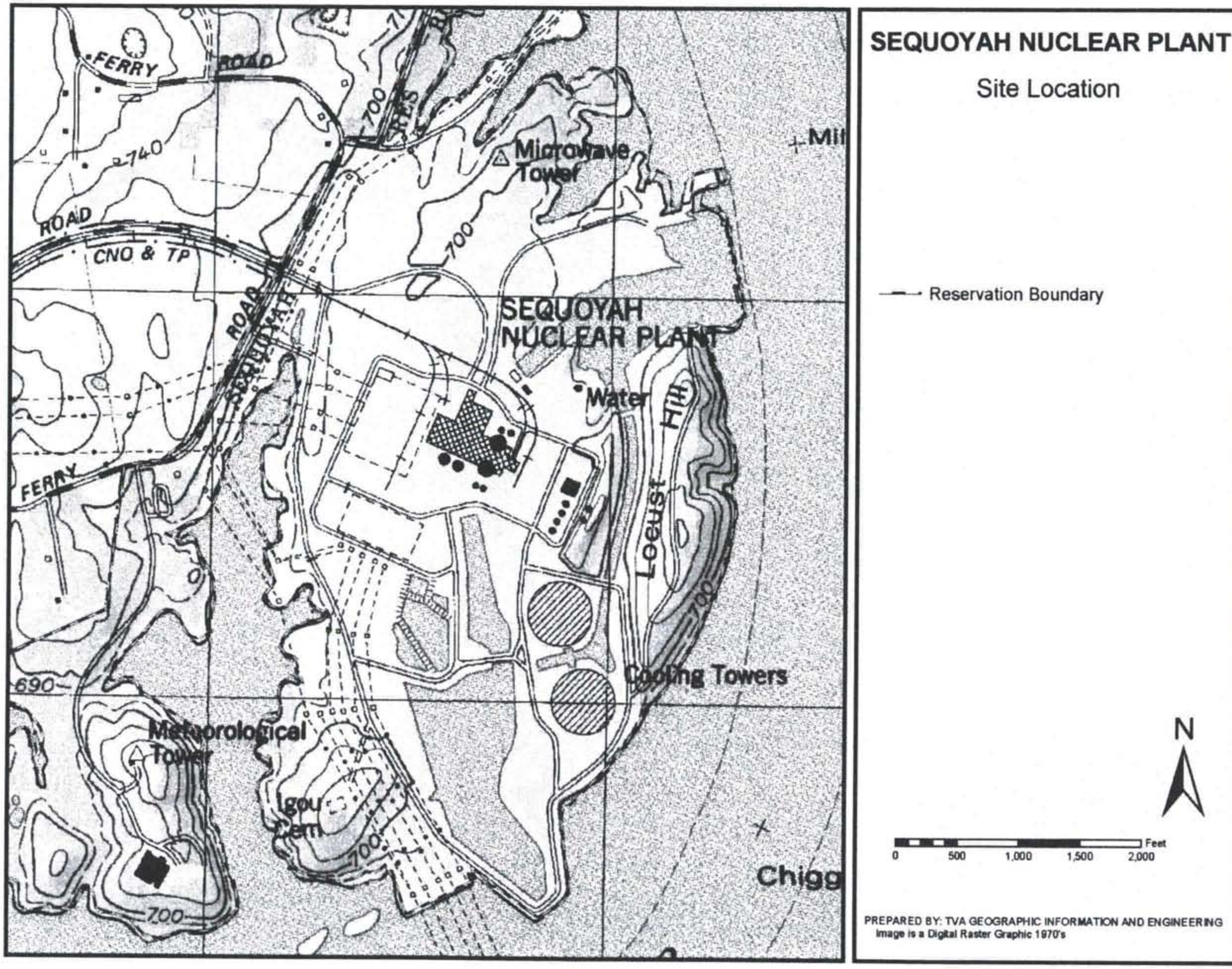


Figure 3.1 Site Location Map

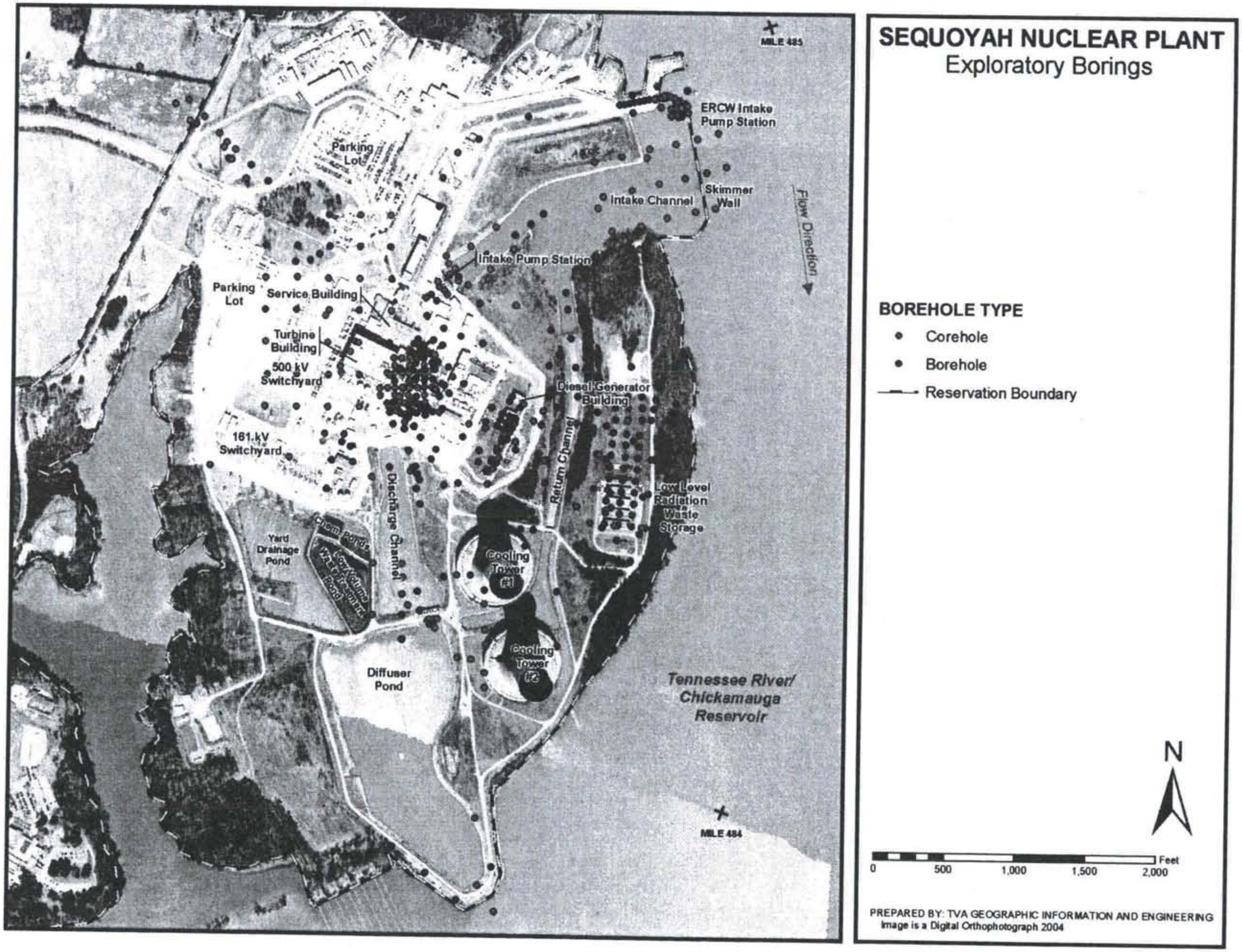


Figure 3.2 Locations of Exploratory Borings

3.2 Physiography

The Valley and Ridge Province is a long narrow belt trending NE-SW that is bordered by the Appalachian Plateau on the west and by the Blue Ridge Province on the east. Geochronologically, this province represents the eastern margin of the Paleozoic interior sea. Structurally, it is part of an anticlinorium, the successor to a geosyncline that sank intermittently for ages as it received sediments from the concurrent rising land surface on the east. The topographic and geologic grain of this subregion is elongated NE-SW in conformity with the trend of the Appalachians region. Viewed empirically, the province is a lowland; an assemblage of long, narrow, fairly even-topped mountain ridges separated by somewhat broader valleys. The ridges are developed in areas underlain by resistant sandstones and more siliceous limestones and dolomites. The valleys have been developed along structural lines in the areas underlain by easily weathered shales and more soluble limestones and dolomites.

Prior to the impoundment of Chickamauga Reservoir, the Tennessee River in the vicinity of SQN had entrenched its course to elevation 640. The small tributary valley floors slope from the river up to around elevation 800 ft-msl, while the crests of the intervening ridges range between 900 and 1000 ft-msl.

Figure 3.3 shows topography at SQN. The majority of the plant site resides at a grade elevation of 705 ft-msl. Elsewhere, terrain is rolling with the highest elevation of about 775 being encountered southeast of the plant site at the top of Locust Hill (LLRWSF site).

3.3 Geomorphology

The SQN site resides near the western border of what was the active part of the Appalachian geosyncline during most of the Paleozoic era. During this time, the area was below sea level and more than 20,000 feet of sedimentary rocks were deposited. At the end of the Paleozoic era, some 250 million years ago, the area was uplifted and subjected to compressive forces acting from the southeast. Folds developed which were compressed tightly, overturned to the northwest, and finally broken by thrust faults along their axial planes. The resultant structure is characterized by a series of overlapping linear fault blocks which dip to the southeast. Since this period of uplift, the area has been subjected to numerous cycles of erosion. This erosion accentuated the underlying geologic structure by differential weathering of the less resistant strata resulting in the development of parallel ridges and valleys which are characteristic of the region.

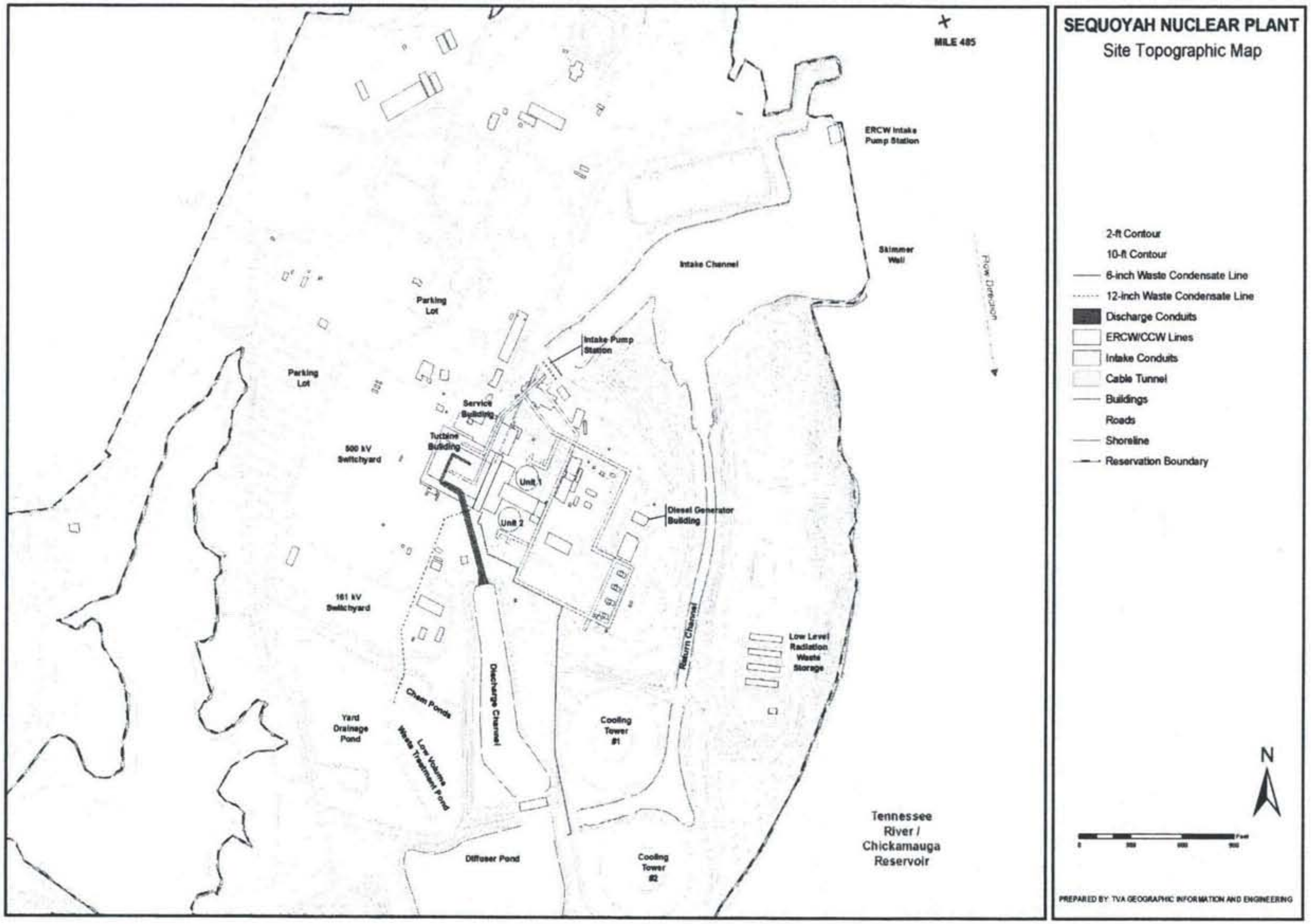


Figure 3.3 Site Topographic Map

3.4 Geology

3.4.1 Stratigraphy

Of the numerous sedimentary formations of Paleozoic age in the plant area, only the Conasauga Formation of Middle Cambrian age is directly involved in the foundation bedrock of the plant (Figure 3.4). Unconsolidated alluvial, terrace, and residual deposits mantle the Conasauga formation at the site. More recent alluvial deposits, that were associated with the floodplain of the Tennessee River, are now covered by the Chickamauga Reservoir.

3.4.2 Bedrock

The Conasauga formation at the site is composed of several hundred feet of interbedded limestone and shale in varying proportions. The shale, where fresh and unweathered, is dark gray, banded, and somewhat fissile in character. The limestone is predominantly light gray, medium grained to coarse crystalline to oolitic, with many shaly partings. A statistical analysis of the cores obtained from the site area indicates a ratio of 56 percent shale to 44 percent limestone. Farther to the southeast and higher in the geologic section, the amount of limestone increases in exposures along the shore of the reservoir.

The general strike of the Conasauga is N30°E and the overall dip is to the southeast, normally steep, ranging from 60° to vertical; however, many small, tightly folded, steeply pitching anticlines and synclines result in local variations to the normal trend.

According to TVA (1979), cavities and solution openings are not a major problem in the site foundation. Most solution openings are restricted to the upper few feet of bedrock near the overburden/bedrock interface. The insolubility of interbedded shale in deeper bedrock functions as a lithologic control to the development of large solution openings. However, small solution openings and partings may exist at greater depths within the bedrock along faults and joints, especially along synclinal zones. Inspection of the walls of the exploratory holes with television disclosed thin, less than 0.05 foot, near-horizontal openings in some of the limestone beds. At the corresponding position, the drill cores showed unweathered breaks. These open partings are interpreted as "relief joints" developed by unloading either from erosion or excavation. The majority was found in the upper few feet of rock, but some were observed as deep as 131 feet below the rock surface.

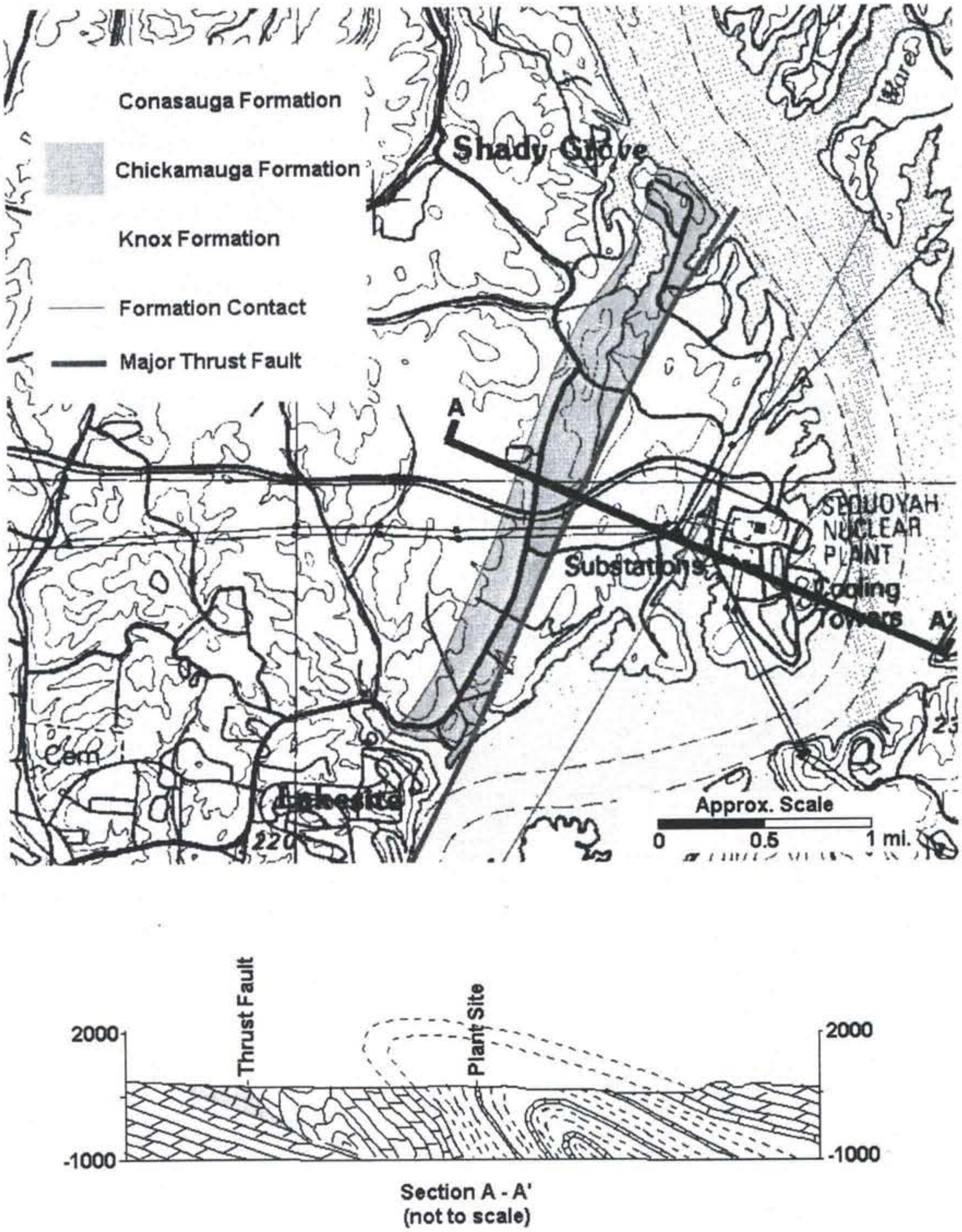


Figure 3.4 Regional Map Showing Geologic Formations and Structure

Figure 3.5 shows the Conasauga bedrock surface based on all available site boring data. As would be expected in a foundation composed of alternating strata of different composition and competency, the configuration of the bedrock surface is irregular (TVA, 1979). The strike of the rock strata is approximately parallel to the centerline of the reactors. Preliminary excavation for foundation investigations (down to 18 inches above design grade) exposed a series of alternating ridges of harder limestone separated by troughs underlain by the softer shale trending across the plant area. The last 18 inches were removed by careful and controlled means so as to limit breakage below the design grade to a minimum. Once foundation grade was reached, the area was carefully cleaned and then inspected jointly by engineers and geologists to determine what, if any, additional material needed to be removed because of weathering or shattering by blasting. Figure 3.6 exemplifies top of rock exposed in the Reactor, Auxiliary, Control, and Turbine Buildings prior to excavation.

After the final excavation was approved, the area was covered either by a coating of thick grout or by a fill pour of concrete to prevent weathering of the shale interbeds due to prolonged exposure. Observation of rock exposed in the foundation areas, examination of cores, and investigations of the walls of exploratory holes with a borehole television camera all indicated that solution cavities or caves are not a major problem in the foundation. Verified cavities generally were limited to the upper few feet or rock where solution developed in limestone beds near the overburden-rock interface. Practically all of this zone was above design grade and was removed.

A consolidation grouting program was performed from February 18 through June 15, 1970 in the foundation areas for the Reactor, Auxiliary, and Control Buildings at the Sequoyah Nuclear Plant. The extent of the area treated is shown in TVA (2005; Figures 2.5.1-9 and 2.5.1-10). The purpose of this program was twofold. The first was to consolidate near-surface fractures predominantly caused by blasting and excavation. The second was to treat any localized open joints, bedding planes, fractures, or isolated small cavities that pre-construction exploratory drilling indicated might be present to a depth of 45 feet below the design foundation grade.

In the excavated area, the contact between the residual material and essentially unweathered rock occurs at an average elevation of 680 ft-msl. The highest design level for the plant foundation grade under the Class I structures is at elevation 665 ft-msl. As a result, the preliminary excavation averaged a minimum of 15 feet in rock. Over most of the area, the rock was suitable for foundation purposes at elevation 665 ft-msl.

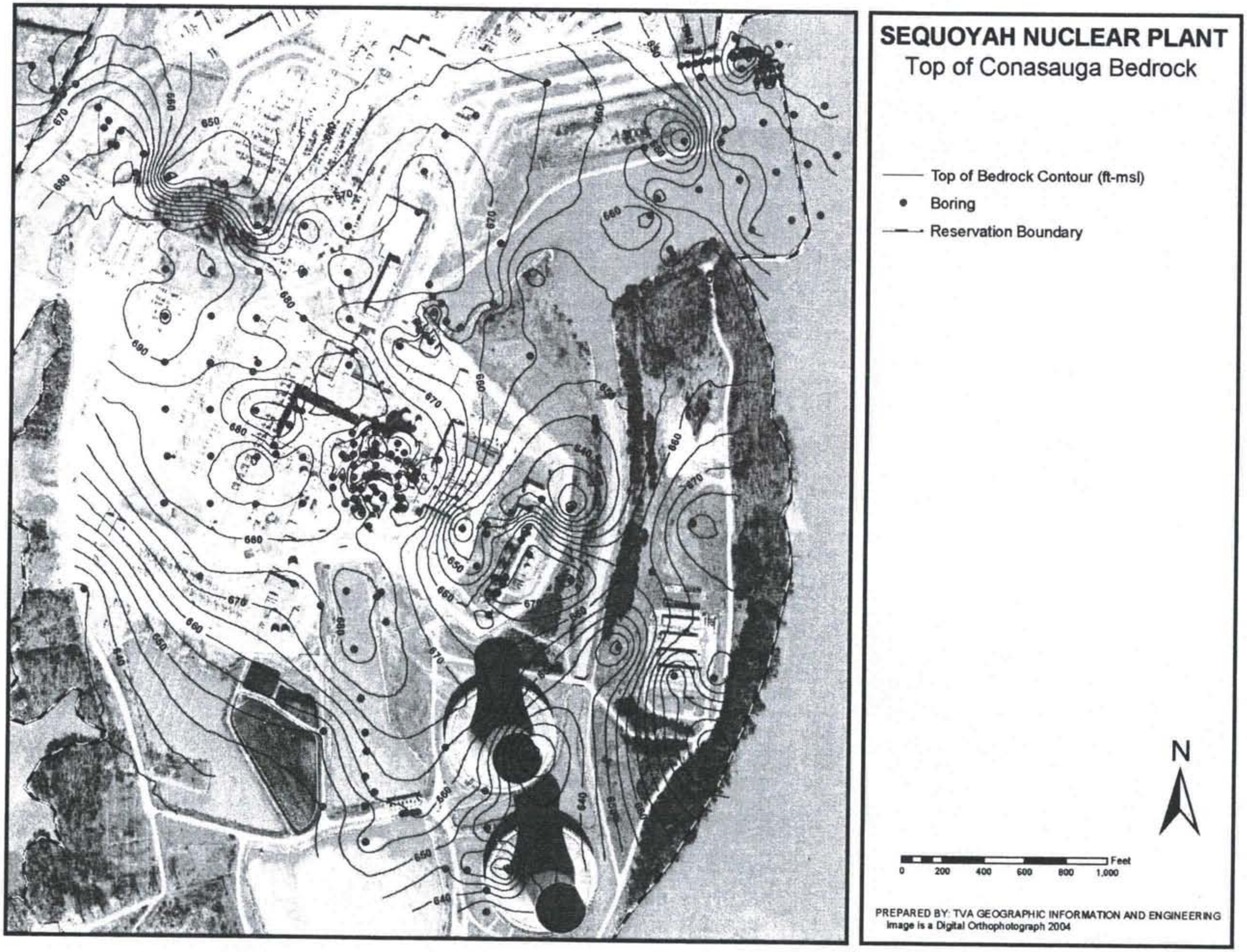


Figure 3.5 Surface of Conasauga Bedrock

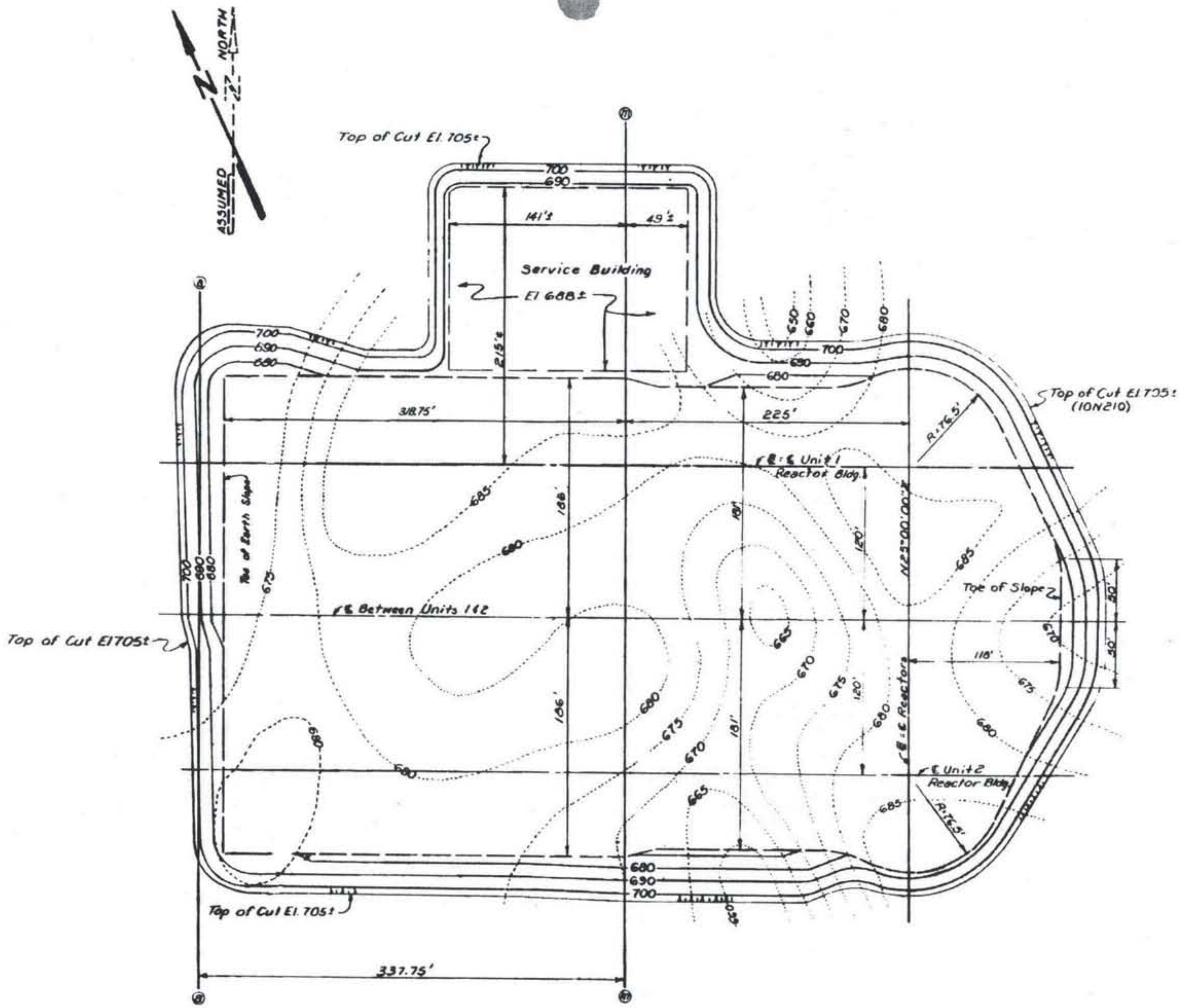


Figure 3.6 Pre-excavation Top of Bedrock Contours (ft-msl) at the Reactor, Auxiliary, Control, and Turbine Buildings (from TVA Drawing 10N211)

In two areas, however, additional rock had to be excavated to remove localized pockets of deeper weathering. These zones were confined in two synclinal areas which crossed the excavation parallel with the north- south baseline. The axis of one lies approximately 70 feet plant east of the baseline and the axis of the other is approximately 140 feet plant west of the baseline. These trough-like synclines had channeled groundwater movement toward and along their axes with the result that weathering had progressed deeper in these areas. Generally, less than 10 feet of additional rock had to be removed from the synclinal zones to obtain a satisfactory foundation; however, in the vicinity of W140; S 220, on the south side of the Auxiliary Building, as much as 30 feet of weathered rock was removed.

3.4.3 Soil

Unconsolidated alluvial, terrace, and residual deposits mantle the Conasauga formation at the site. More recent alluvial deposits that were associated with the floodplain of the Tennessee River are now covered by the Chickamauga Reservoir. Alluvium within the area of the main plant site was removed during construction and only residual soils remain. In the plant area not mantled by terrace deposits, the Conasauga is overlain by varying thicknesses of residual silt and clay derived from weathering of the underlying shale and limestone. The residual soils are primarily silts and clays grading downward into saprolitic shale of the Conasauga. In a few localized areas weathered shale is exposed at the ground surface. However, in most exploratory drilling the residuum depths ranged from 3 to 34 ft.

A pre-construction soils exploration program was conducted at the plant site to determine the static physical characteristics of the soils. Standard split-spoon borings and undisturbed borings were made. Grain size analyses shows that soils across the site range from fat clay residual material to sand and gravel terrace deposits.

The age of unconsolidated material at SQN is in excess of 30,000 years. No carbonaceous soil was encountered in site excavation and no other dating criteria could be established (TVA, 1979). Carbon 14 dates from material found in high alluvial terrace deposits at the Watts Bar Nuclear Plant located about 38 miles northeast of Sequoyah placed the age of the material at 32,400 years.

Terrace deposits overlie residuum with varying thickness across the site. Terrace material consists predominantly of sandy clay with embedded rounded cobbles and pebbles of quartzite, quartz and chert. This material represents deposition at a time when the river was flowing at a higher elevation during an earlier erosion cycle. According to TVA (1979), a maximum thickness of 45 feet of terrace deposits was encountered in exploratory drilling in the topographically high areas southeast of the site, and it is quite probable that greater thicknesses exist under the highest portion of this area (i.e., Locust Hill). Evidence suggests that residual material has essentially been eroded away under Locust Hill with terrace deposits directly overlying bedrock. This hill is the location of the LLRWSF.

Based upon more extensive borings, Boggs (1982) describes the Low Level Radwaste Storage Facility (LLRWSF) site as being underlain by residual and alluvial soils generally consisting of clay and silt with minor amounts of sand and gravel. According to Boggs (1982), soil thickness averages about 50 feet within the LLRWSF area, but varies radically over short distances due to a highly irregular bedrock surface configuration. Fill/spoil material was also used as foundation material beneath the LLRWSF.

In situ soil dynamic studies were made at the plant site to obtain data for computation of elastic moduli for earthquake design criteria. The areas investigated at the site were the Diesel Generator Building, the LLRWSFs, the ERCW pipeline, the Additional Diesel Generator Building, and the Primary Water Storage Tank.

Prior to and during construction, borrow investigations were made on an as-needed basis. The borrow samples were tested by the central materials laboratory according to ASTM D-698 to develop compaction control curves. The compaction curves were divided into subclasses to control compaction of earthfill at the site. At SQN, Type A backfill (sandy to silty clay) was placed around all Category I structures. This material, which was selected earth placed in not more than 6-inch layers, has a minimum required compaction of 95 percent of the maximum dry density at optimum moisture content. The limits of excavation and the backfill around Category I structures can be visualized in Figure 3.7.

A free-draining granular fill material, consisting of crushed stone or sand and gravel, was placed below or next to Category I structures. This material was obtained commercially from off-site sources. The granular fill was suitable for compaction to a dense, stable mass and consisted of sound, durable particles which are graded within the following limits:

	Percent by Weight	
Passing	**Minimum**	**Maximum**
1¼-inch	100	
1-inch	95	100
¾-inch	70	100
⅜-inch	50	85
No. 4	33	65
No. 10	20	45
No. 40	8	25
No. 200	0	10

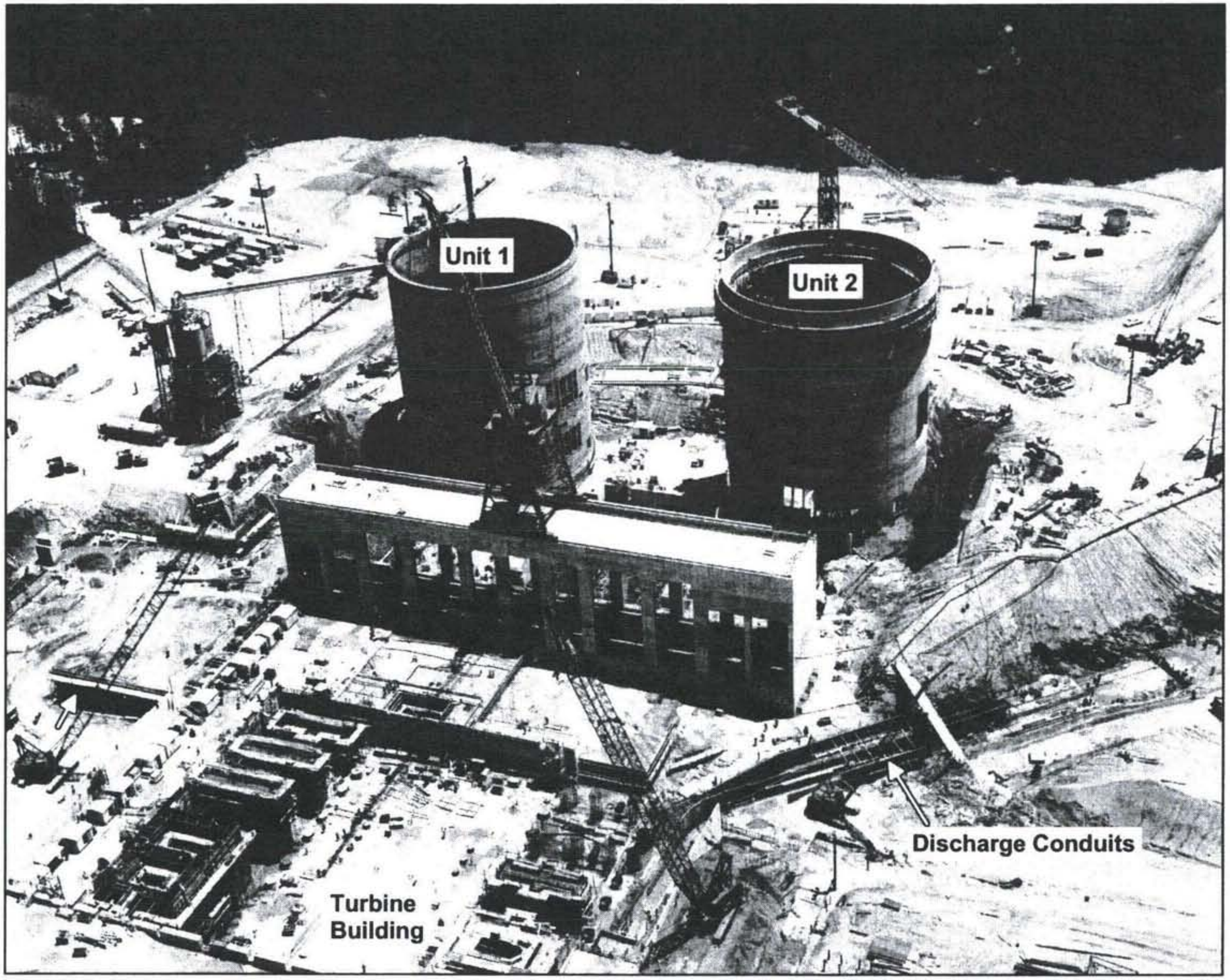


Figure 3.7 1971 Site Construction Photograph of the Reactor, Auxiliary, Control, and Turbine Buildings

A crushed rock material that meets the gradation requirements shown below was used for remedial treatment in local areas. This was generally done where moisture caused the soil to be unsatisfactory as a base for earthfill placement. The material was used in a limited area at the RWST pipe tunnel. The material was placed in approximate 6-inch loose layers and rolled into the soil. If the required stiffness for the placement of earthfill was achieved, lifts of earth-fill or crushed stone fill were placed. If the required stiffness was not achieved, then additional lifts of the material were placed and rolled to obtain the desired stiffness. If shearing or pumping occurred in placement of the first lift, additional lifts of the material were placed as necessary.

	Percent by Weight	
Passing	**Minimum**	**Maximum**
3-inch	95	100
2-inch	25	55
1½-inch	0	15
1-inch	0	2

3.4.4 Structure

The controlling features of the geologic structure at the Sequoyah plant site are the Kingston Thrust fault (Figure 3.4) and a major overturned anticline that resulted from the movement along the fault. This fault lies about a mile northwest of the plant site (Figure 2.5.1-2), and can be traced for 75 miles northeastward and 70 miles southwestward. The fault dips to the southeast, under the plant site, and along it steeply dipping beds of the Knox dolomite have been thrust over gently dipping strata of the Chickamauga limestone. The distance from the plant site, about one mile, and the dip of the fault, 30 degrees or more, will carry the plane of the fault at least 2000 feet below the surface at the plant site.

The major overturned anticline results in the Conasauga formation at the plant site resting upon the underlying Knox dolomite which normally overlies it. As a result of the ancient structural movement of the fault and major fold, the Conasauga formation at the plant site is highly folded, complexly contorted, and cut by many very small subsidiary faults and shears. The general strike of these beds are N 30°E and the overall dip is to the southeast, but the many small tightly folded, steeply pitching anticlines and synclines result in many local variations to the normal trend.

In some of the drill cores, small faults and shears were noted intersecting the bedding at various angles. These dislocations are the result of shearing along the limbs of the minor folds which developed contemporaneously with the major movement along the Kingston fault.

3.5 Hydrology

The SQN site is in the eastern Tennessee portion of the Southern Appalachian region, which is dominated much of the year by the Azores-Bermuda anticyclonic circulation. This circulation over the southeastern United States is most pronounced in the fall and is accompanied by extended periods of fair weather and widespread atmospheric stagnation. In winter, the normal circulation pattern becomes diffuse as the eastward moving migratory high and low pressure systems, associated with the midlatitude westerly current, bring alternating cold and warm air masses into the area with resultant changes in wind direction, wind speed, atmospheric stability, precipitation, and other meteorological elements. In summer, the migratory systems are less frequent and less intense, and the area is under the dominance of the western edge of the Azores-Bermuda anticyclone with a warm moist air influx from the Atlantic Ocean and the Gulf of Mexico (TVA, 2005).

The climate of the watershed above SQN is humid temperate. All recharge to the groundwater system at the plant site is from local precipitation, which averages around 51 inches per year.

The Tennessee River above SQN site drains 20,650 mi^2. Chickamauga Dam, 13.5 miles downstream, and Watts Bar Dam upstream (TRM 529.9) affect water surface elevations at the Plant. Peaking hydropower operations of the dams cause short periods of zero and reverse flow near the plant. Based upon discharge records since closure of Chickamauga Dam in 1940, the average daily streamflow at the site is 32,600 cfs (TVA, 2005).

Chickamauga Reservoir water elevations vary seasonally according to operations for power production, navigation, and recreation. The operating guide for Chickamauga Dam is shown in Figure 3.8. As shown in Figure 3.9 elevations of the SQN Discharge Channel correlate with the operating guide. This is associated with plant operations during warmer months that are designed to comply with reservoir thermal release limits.

During high flow periods, the top of the normal operating zone may be exceeded for the regulation of flood flows. During the late spring and summer, TVA varies the elevation of Chickamauga Reservoir to aid in controlling mosquito populations. Elevations are lowered during the week and raised a foot on weekends, to strand mosquito eggs and larvae on the shoreline. Normal full pool elevation is 683.0 ft-msl. At this elevation, the reservoir is 58.9 miles long on the Tennessee River and 32 miles long on the Hiwassee River. The reservoir is approximately 3,000 feet wide at the site, with depths ranging from 12 feet to 50 feet at normal full pool elevation. Probable maximum flood elevation is 722.6 (TVA, 1979).

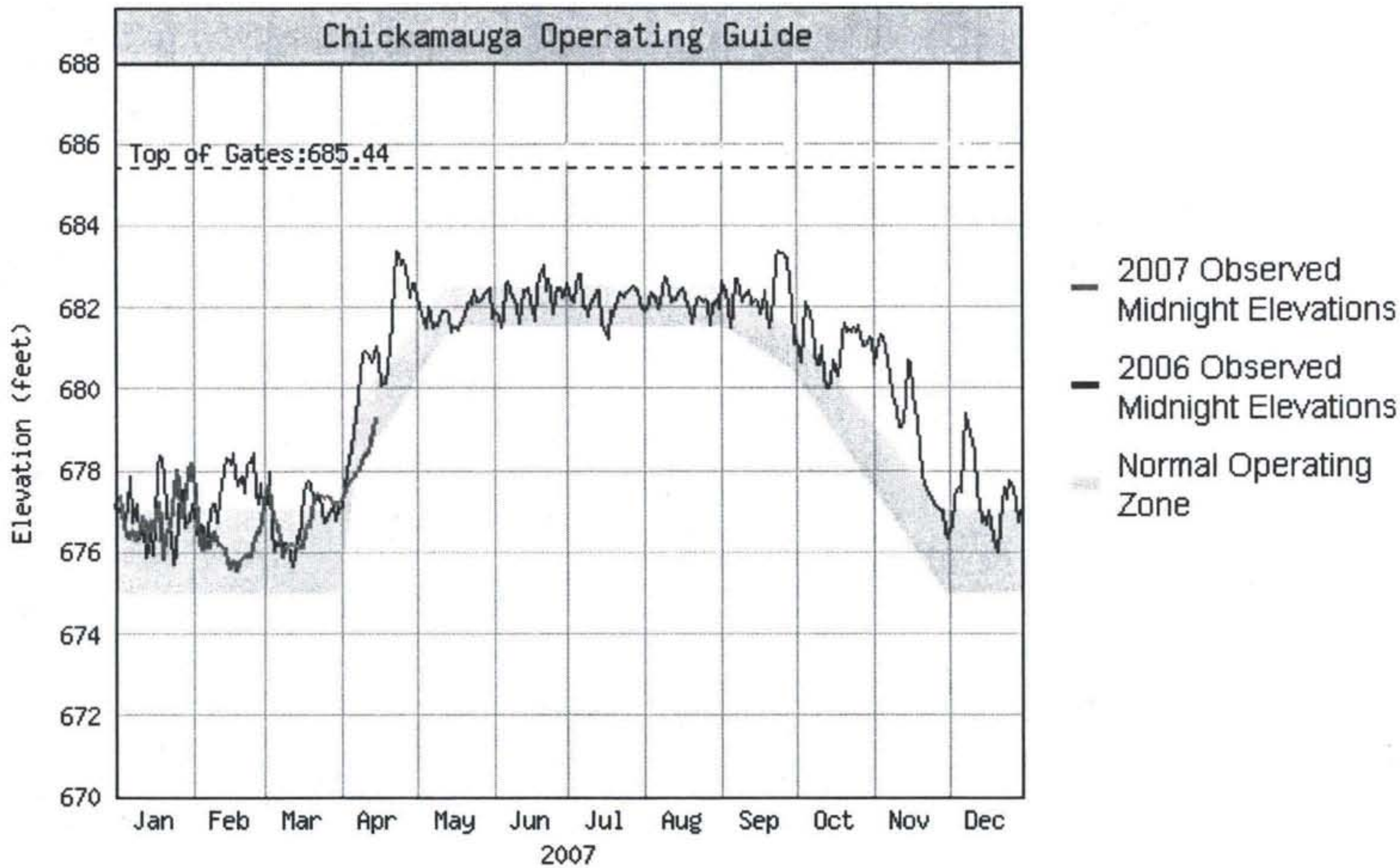


Figure 3.8 Operating Guide For Chickamauga Dam

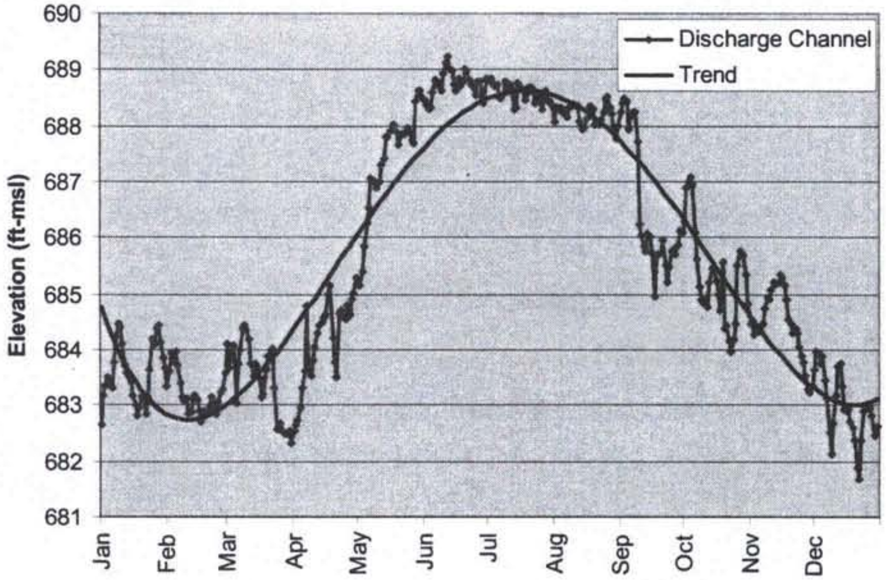


Figure 3.9 Mean 1995 – 1999 Discharge Channel Elevations

3.6 Groundwater

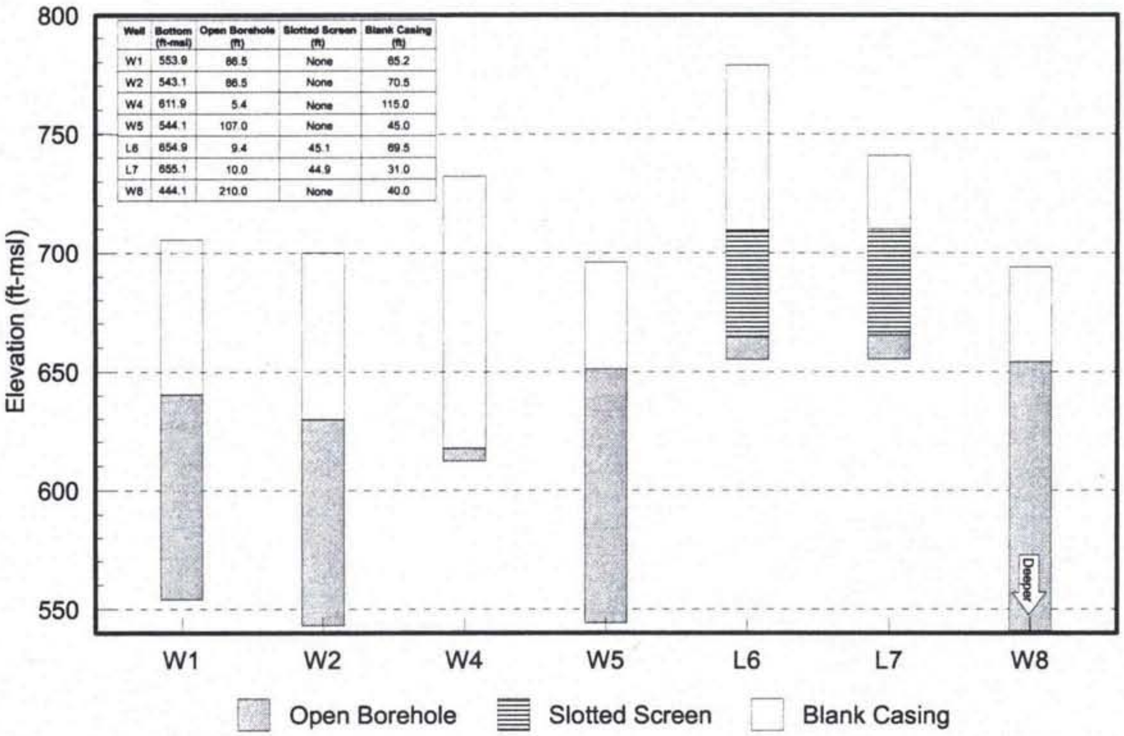
The peninsula on which SQN is located is underlain by the Conasauga, a poor water-bearing formation. About 2,000 feet northwest of the plant site, the trace of the Kingston Fault separates the Conasauga Shale from a wide belt of Knox Dolomite (Figure 3.4). The Knox is a major water-bearing formation of eastern Tennessee. Based on a comprehensive examination of bedrock coreholes (TVA, 1979), groundwater in the Conasauga occurs in small openings along fractures and bedding planes; these rapidly decrease in size with depth, and few openings exist below a depth of 300 feet.

There is no groundwater use at SQN. The source of groundwater at SQN is derived from incipient infiltration of precipitation. Within overburden soils at the site, groundwater movement is generally downward. Local areas of natural lateral flow likely occur near some streams, topographic lows, and where extensive root systems exist. Anomalous groundwater movement might also occur in areas that have experienced soil unraveling and in the vicinities of pipelines (especially those with relatively permeable bedding and fill).

Groundwater movement is expected to occur mainly along strike of bedrock, to the northeast and southwest, into Chickamauga Reservoir. Groundwater also discharges from overburden soils into the reservoir, site drainage channels (i.e., Discharge Channel), and surface water impoundments (i.e., Diffuser Pond). Higher surface water levels of Chickamauga Reservoir (April – October) result in corresponding rises in the groundwater table and the lateral extent of this effect varies with groundwater hydraulic gradients. Lower levels of Chickamauga Reservoir (November – March) result in corresponding declines in the water table along the reservoir periphery.

Pre-construction boring logs collected by TVA (1979) suggest that groundwater transmissivity across the strike in the Conasauga formation is extremely low. Local variations in hydraulic conductivity within the shallow bedrock are primarily controlled by geologic structure and stratigraphy. Shale beds and clay seams provide lithologic restrictions to the vertical movement of groundwater. The Conasauga/Knox contact northwest of the plant has been described as a hydraulic boundary; however, no field testing has been conducted to verify this assumption. Bedrock porosity is estimated to be about 3 percent based upon results of exploratory drilling.

Prior to the current study, a total of eight (8) long-term bedrock monitoring wells had been installed at the SQN site. Figure 3.10 indicates the depth of open borehole and/or screened interval for each well and wells are located as shown in Figure 1.2. Well construction details are provided in Appendix A.



Well	Bottom (ft-msl)	Open Borehole (ft)	Slotted Screen (ft)	Blank Casing (ft)
W1	553.9	86.5	None	65.2
W2	543.1	86.5	None	70.5
W4	611.9	5.4	None	115.0
W5	544.1	107.0	None	45.0
L6	654.9	9.4	45.1	69.5
L7	655.1	10.0	44.9	31.0
W8	444.1	210.0	None	40.0

Figure 3.10 Site Bedrock Monitoring Wells

Long-term groundwater level data have been collected to establish temporal trends for six wells at the SQN site. Since these monitoring wells are developed in bedrock and weathered bedrock, any deductions regarding groundwater movement is restricted to this flow regime. Figure 3.11 shows water level data obtained for wells W1, W2, L6, and L7. The plot indicates that groundwater levels measured for wells W1 and L6 are strongly influenced by reservoir stage. The fluctuation in groundwater levels at well L6 is almost completely correlated with the cyclic operation of the reservoir. Well W1 exhibits water levels that also correspond with the periodicity of reservoir stage; however, reservoir effects are diminished for times around 1986 and 1988. This might be attributed to drought conditions and diminished precipitation at the site during these times. The hydrographs for wells W2 and L7 appear to be influenced by water retention basins on the south side of the plant and do not display reservoir stage effects. Well W2 is located near the Yard Drainage Pond and well L7 is in the vicinity of the Return Channel. There is a large degree of correlation between water levels in the two wells and this may be related to plant discharges and pond operations. The free water surface in the Return Channel is maintained at a higher elevation than the reservoir by a discharge flume and weir. The minimum normal water surface elevation in the Return Channel is given as 689 ft-msl according to TVA drawing number 31W600-2. The average horizontal hydraulic gradient from well L7 to L6 is 0.01 ft/ft. The average horizontal hydraulic gradient from well W1 to W2 is about 0.003 ft/ft.

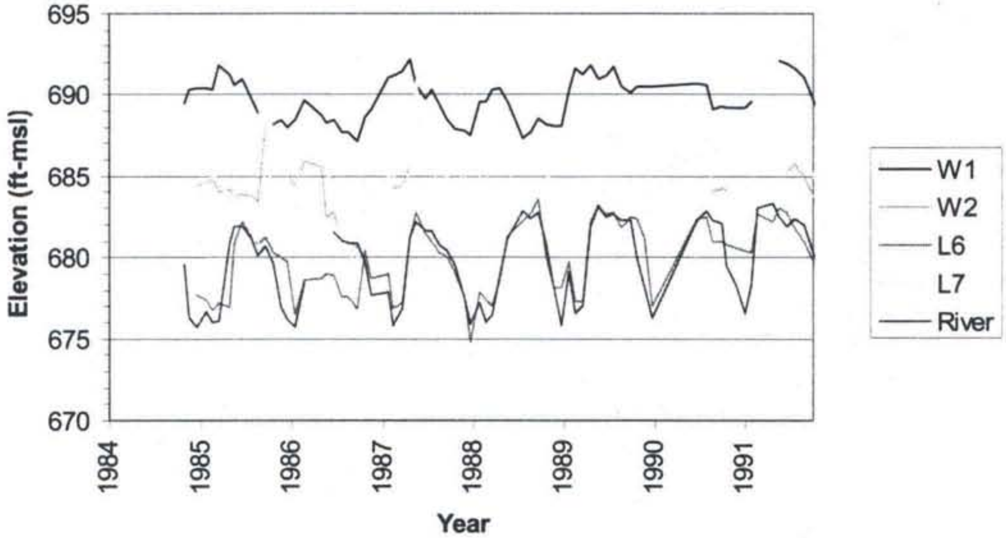


Figure 3.11 Time-Series Groundwater Levels for Wells W1, W2, L6, and L7 (1985-1991)

Figure 3.12 shows groundwater elevations for wells W1, W4, W5 and L7. This plot also indicates that the Return Channel and the Discharge Channel influence groundwater elevations in the southeastern area of the SQN site. The average horizontal hydraulic gradient from well W4 to L7 is approximately 0.0071 ft/ft; from well W1 toward the Intake Channel it is about 0.007 ft/ft; and from well W4 to W5 it is approximately 0.004 ft/ft.

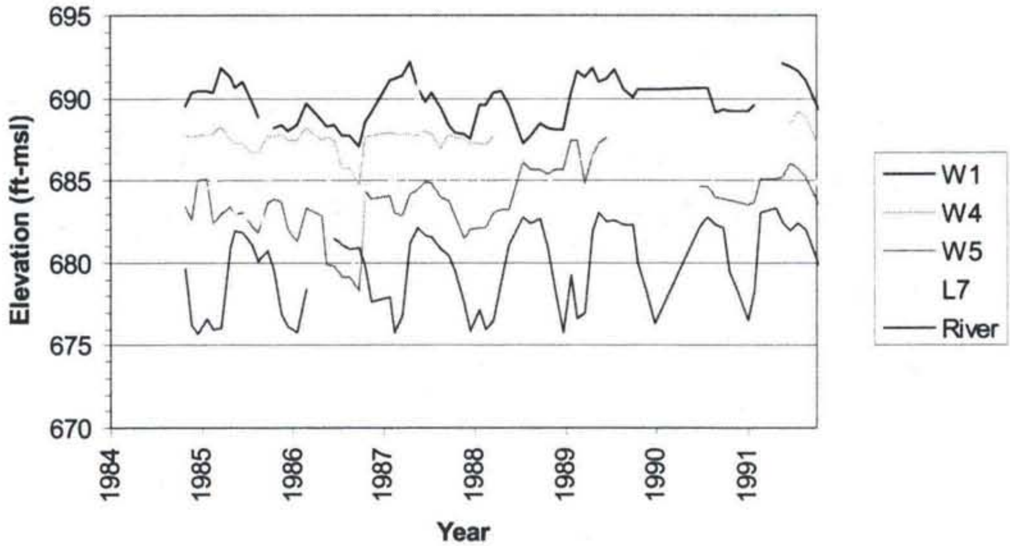


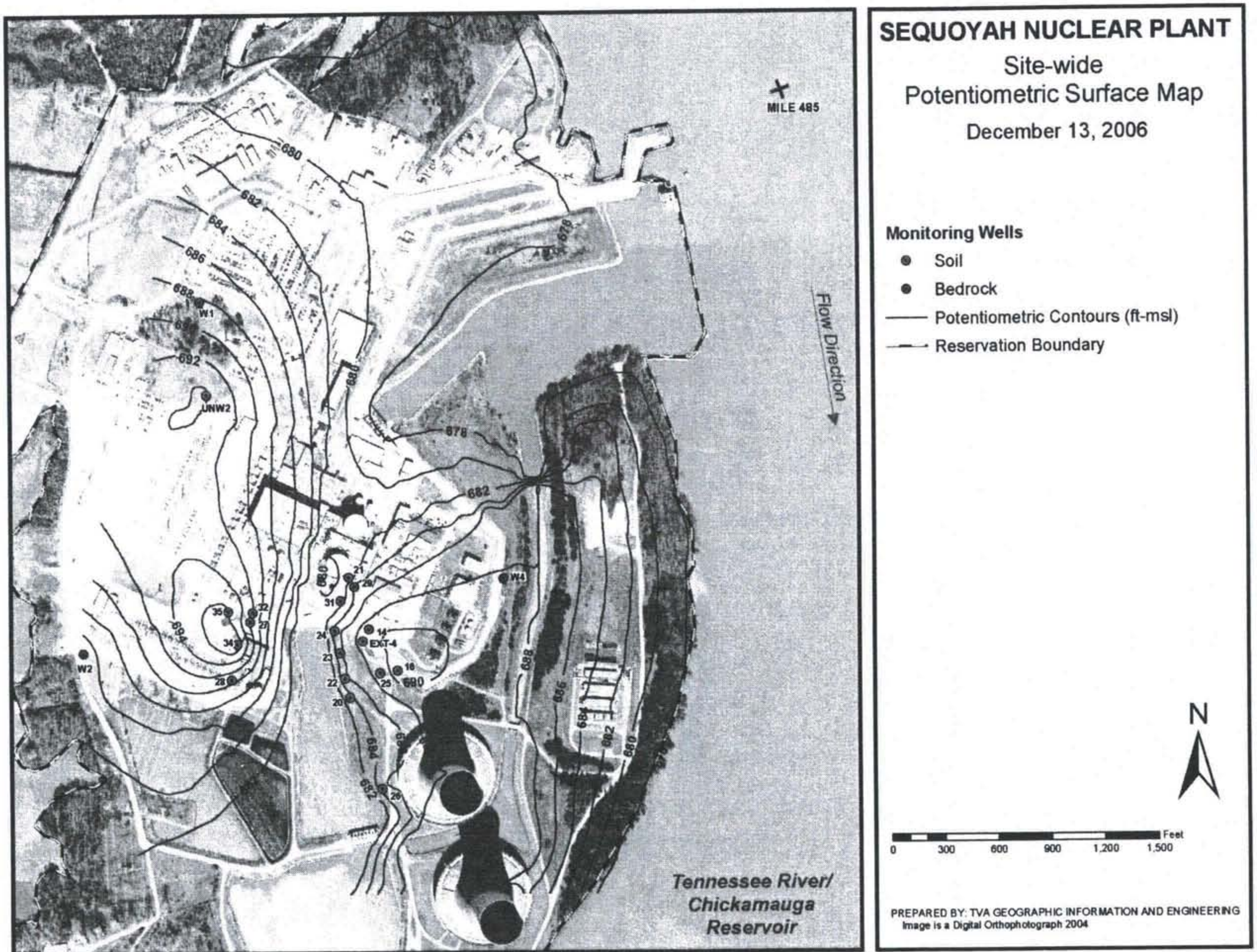
Figure 3.12 Time-Series Groundwater Levels for Wells W1, W4, W5 and L7 (1985-1991)

The direction of regional groundwater movement is primarily towards the SQN Intake and Discharge Channels based on historical and recent (12/13/2006) potentiometric mapping (Figure 3.13). Exceptions to this directional flux have occurred locally due to leaking water lines serving the site; in areas of topographic highs/lows; and from dewatering operations of the Diesel Fuel Oil Interceptor Trench.

Extensive pre-construction characterization studies were conducted at the plant site to determine the static physical characteristics of the soils. However, few field tests or laboratory measurements were performed to assess the hydraulic properties of site soils and bedrock. Laboratory permeameter testing of an undisturbed residual soil sample (boring US-53; TVA, 1979) indicates horizontal and vertical hydraulic conductivity values of 7.8E-07 and 1.3E-08 cm/s (a ratio of 1:60). A statistical summary of soil hydraulic properties at the LLRWSF (Table 3.1) suggests that residual soils and alluvium might be expected to exhibit saturated K values ranging from 5.8E-06 to 3.4E-09 cm/s.

Table 3.1 Statistical Summary of Soil Properties (from TVA, 1981)

Parameter	Minimum	Mean	Maximum	Standard Deviation	No. of Samples
Porosity	0.31	0.53	0.70	0.10	257
Density (lb/ft^3)	51.3	81.1	116.8	16.5	263
Saturated Hydraulic Conductivity (cm/s)	3.4E-09	7.9E-07	5.8E-06	1.8E-06	19
Natural Saturation (%)	41.0	93.0	100.0	9.0	263



SQN_Potentiometric_Surface_sitewide_map10.mxd - April 17, 2007

Figure 3.13 Site-Wide Potentiometric Map

Sorptive characteristics of soils beneath the LLRWSF have been determined through laboratory testing of soil samples (Rogers, 1982). Batch techniques were used on composite samples to measure distribution coefficients (K_d) for radionuclides identified in Table 3.2. The sorptive capacity of the Conasauga was not measured at the time due to the lack of a recognized procedure for obtaining realistic K_d values for rock cores. Table 3.2 summarizes laboratory K_d results for LLRWSF soils.

Table 3.2 Soil Distribution Coefficients (K_d)

Radionuclide	Kd (mL/g)		
	Minimum	Mean	Maximum
Co-58/60	1,740	4,820	8,000
Cs-134/137	850	2,390	>10,000
Sr-90	26	36	43
Mn-54	1,000	1,589	2,200
Zn-65	10,400	>10,400	>10,400

During investigations of the diesel fuel oil release, laboratory permeameter testing of undisturbed soil samples at well W14 (Edwards et al., 1993) provided vertical hydraulic conductivity values of 3.9E-07 and 1.6E-04 cm/s at depths of 8-10 and 23-25 ft, respectively. Both samples were characterized as clayey sands. The disparity in these hydraulic conductivity values prompted aquifer testing at the site by Julian (1993) to support final characterization and design of the Diesel Fuel Oil Interceptor System (Figures 3.14 and 3.15).

Single-well pump tests and Electromagnetic Borehole Flowmeter surveys (Young et al., 1997) were conducted by Julian (1993) at wells 22, 23, and EXT-4. The vertical distribution of horizontal hydraulic conductivity at each well is provided in Table 3.3. Incremental horizontal hydraulic conductivity ranged from 6.2E-07 to 1.9E-04 cm/s among all test wells.

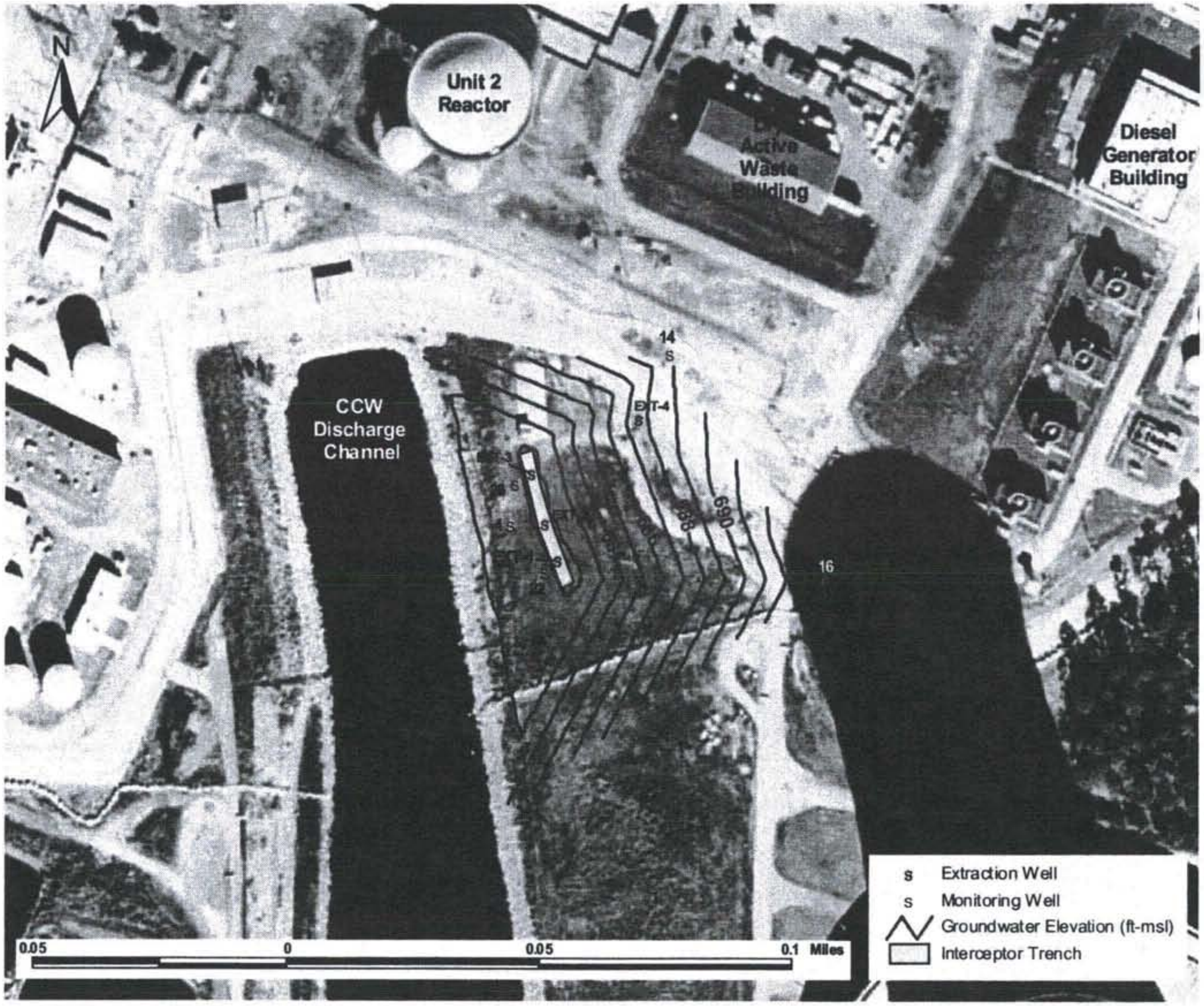
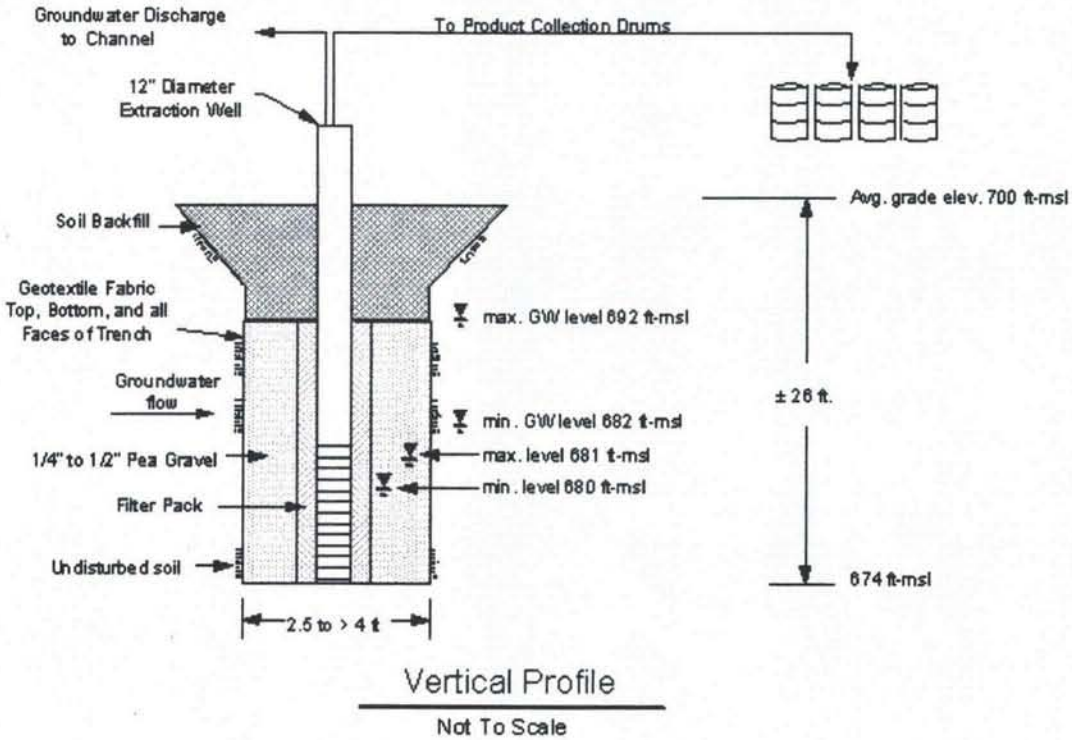


Figure 3.14 Potentiometric Surface at Diesel Fuel Oil Interceptor System on February 10, 2003



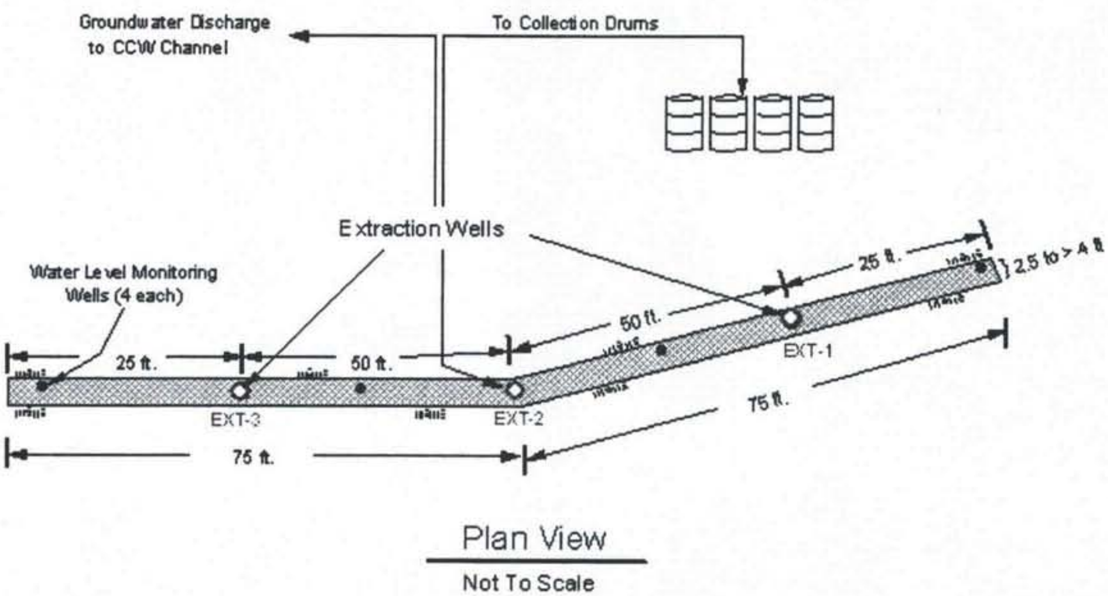


Figure 3.15 Schematic of Diesel Fuel Oil Interceptor Trench

Table 3.3 Horizontal Hydraulic Conductivity Values from Single-Well Testing at Wells 22, 23, and EXT-4

Elevation (ft-msl)	Horizontal Hydraulic Conductivity (cm/s)		
	Well 22	Well 23	Well EXT-4
676.4	5.4E-05		
676.7	1.2E-04		
677.7	1.8E-05		1.2E-04
678.7	4.6E-05		8.5E-05
679.7	3.7E-05		6.7E-05
680.7	4.0E-05	2.3E-05	1.4E-04
681.7	2.8E-05	1.5E-04	1.8E-05
682.7	3.0E-05	1.9E-04	8.2E-06
683.7	3.8E-05	1.4E-04	1.3E-04
684.7	7.3E-06	1.1E-04	6.7E-05
685.7	1.1E-05	5.1E-05	1.8E-04
686.7	8.1E-07	2.6E-05	1.9E-05
687.7	4.8E-06	1.7E-05	1.2E-05
688.7	3.2E-06	9.9E-06	1.1E-05
689.7	8.9E-06	1.7E-05	1.4E-06
690.7	3.2E-06	1.1E-06	6.8E-06
691.7	4.8E-06		1.2E-06
692.7	6.2E-07		
average =	2.5E-05	6.6E-05	5.7E-05

3.7 Offsite Water Supplies

3.7.1 Offsite Groundwater Supplies

When SQN was initially evaluated in the early 1970s, it was in a rural area, and only a few houses within a two-mile radius of the plant site were supplied by individual wells in the Knox Dolomite (TVA, 1979). Because the average domestic use probably did not exceed 500 gallons per day per house, groundwater withdrawal within a two-mile radius of the plant site was less than 50,000 gallons per day. Such a small volume withdrawal over the area would have essentially no effect on area groundwater levels and gradients. Although development of the area has increased, public supplies are available and overall groundwater use is not expected to increase.

TVA (2005) provide tabulated data of wells and springs located within a 20-mile radius of the site from 1985 surveys. Julian (2000) provides results from a United State Geological Survey (USGS) Ground-Water Site Inventory (GWSI) database retrieval for wells in Hamilton County. The data are a combination of domestic wells, wells installed for specific investigations, and other groundwater sites. Table 3.4 provides the results of this retrieval from the GWSI for

Hamilton County in the vicinity of SQN. Large capacity (i.e., discharge >100 gpm) well locations from the GWSI database are depicted in Figure 3.16.

Table 3.4 Wells in the Vicinity of SQN from GWSI Database

Well Number	Latitude	Longitude	Depth (ft)	Discharge (gpm)	Aquifer
Hm:N-090	351147	851308	67	5,400	
Hm:N-089 HIXSON NO.3 PUMP	351148	851353	177	4,000	Newman Limestone
Hm:0-018	350750	850458	148	2,000	Chepultepec Limestone
Hm:O-030 SAVANNAH VALLEY	351114	850252	145	1,500	
Hm:O-016	351424	850039	158	900	
Hm:O-015	351428	850036	262	800	Knox Group
Hm:O-008	351428	850039	120	760	
Hm:J-016 EASTSIDE	350719	850509		400	Knox Group
Hm:O-031	351115	850250	150	350	
Hm:N-048 BINKLEY, S.DENT	351041	851237	180	300	
Hm:N-056 THRASHER RR	351239	851250	103	300	Paleozoic
Hm:N-075 FREEMAN WELL	351158	851117	202	270	
Hm:N-083 USGS-TDOT	351150	851405	202	260	
Hm:J-015 EASTSIDE +DUP	350720	850510	182	250	Knox Group
Hm:O-003	351054	850238	250	250	
Hm:N-060 OLDAKER 14	351228	851010	144	250	Paleozoic
Hm:N-059 WALKER 14A	351249	851101	223	245	Paleozoic
Hm:N-086 USGS-REEVE	351407	851147	202	240	
Hm:R-015	352038	850813	390	200	
Hm:O-007	351437	850027	247	170	
Hm:R-005 UNION-FORK/BAKE	352031	850819	193	160	
Hm:R-073 NORRIS WELL	351525	850853	190	150	
Hm:O-017 EASTSIDE	350735	850530	280	105	Knox Group
Hm:J-013 EASTSIDE	350607	850510	251	100	Knox Group
Hm:J-014 EASTSIDE	350655	850520	250	100	Knox Group
Hm:N-084 USGS-CONARD	351320	851320	202	100	
Hm:R-004	352031	850816	330	70	
BOWMAN WELL AT SALE CR	352532	850848	1,310	40	
Hm:O-041	351206	850307	112	20	
Hm:S-008	351522	850417	75	20	
Hm:N-054 FLOYD THRASHER	351223	851252	279	19	
Hm:S-007	351943	850049	60	16	
Hm:J-001	350614	850047	80	15	
Hm:N-002	350953	850843	100	15	
Hm:J-002	350504	850246	160	10	
Hm:N-046 HUD QUARRY	350937	851314	242	7	Paleozoic
Hm:N-078 NOE	351320	850740	280	7	
Hm:O-074 VINCENT WELL	351432	850637	342	7	
Hm:S-006	351549	850516	269	5	
Hm:N-049 RAGAN HUD	351137	851341	270	2	

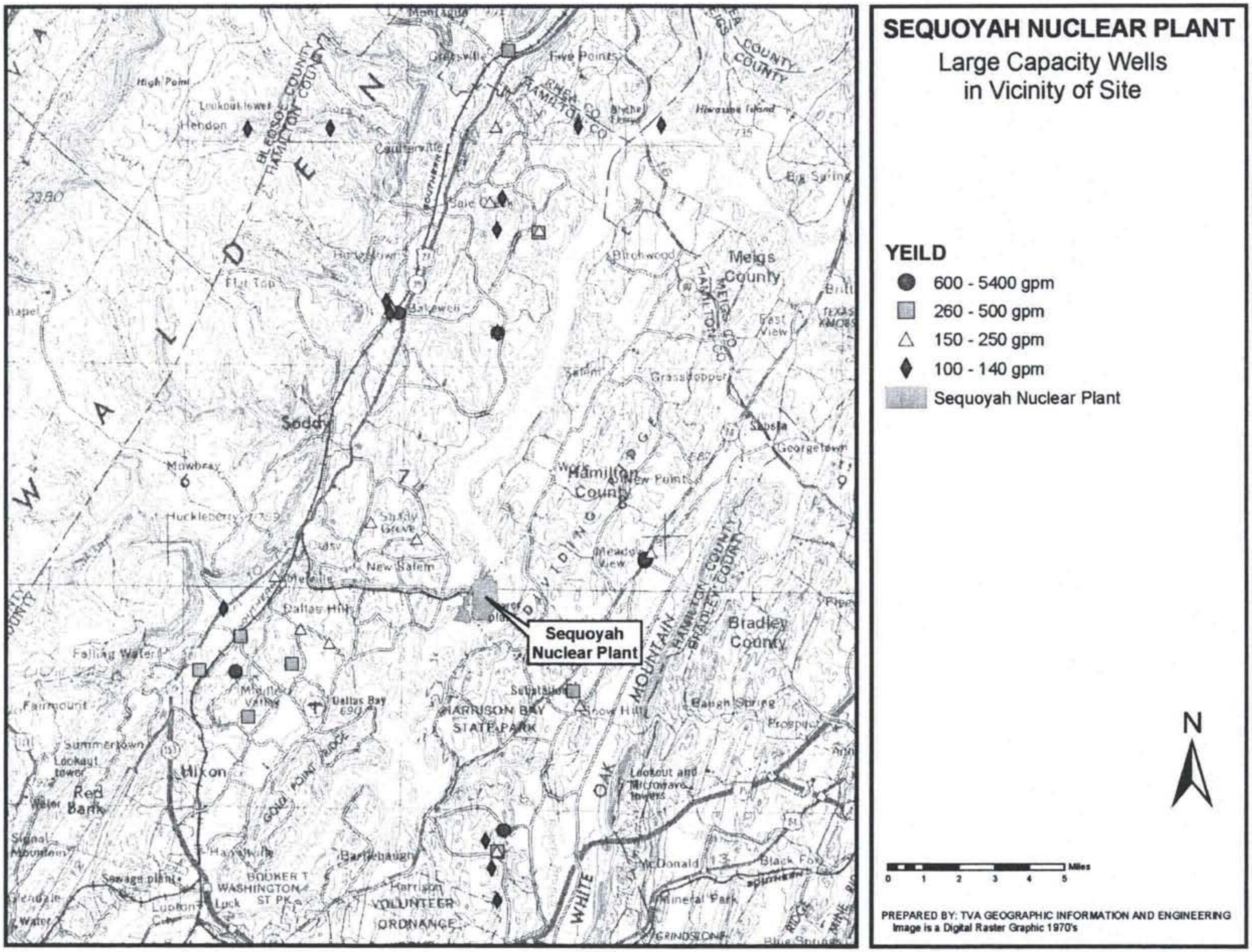


Figure 3.16 Large Capacity Wells in the Vicinity of SQN from USGS GWIS Database

Bradfield (1992) conducted a study of Cave Springs from 1987 to 989. This the second largest spring in East Tennessee and an important water supply. Cave spring is located approximately 8 miles southwest of SQN near state Highway 27. In addition to wells in the immediate vicinity of Cave Spring, Bradfield (1992) examined water groundwater quality/quantity for water supply wells in the region. Table 3.5 lists attributes of wells included in the study and Figure 3.17 shows the well locations relative to SQN.

Table 3.5 Wells in the Vicinity of SQN from Bradfield (1992)

Well Number	Ground Elevation (ft-msl)	Well Depth (ft)	Casing Depth (ft)	Soil Thickness (ft)	Estimated yield (gpm)	Depth Water-Bearing Zone(s) (ft)
1	710	71	61	25	3,000	65-70
2	710	73	63	25	3,000	65-70
3	710	398	82	25	>300	160, 190 260, 275, 320
4	710	177	140	25	>4,000	167-173
6	661	322	148	127	300	180, 270
7	820	298	296	298	15	160-180, 270-290
8	880	231	226	231	5	200-231
9	685	103	93	37	400	59-71, 75-93, 98-103
11	786	223	180	179	400	201-220
12	723	142	95	95	200	95-131
13	730	242	147	50	100	50-70, 177
14	850	302	130	124	<1	150-200
15	827	202	194	202	30	143-147, 197-202
16	770	251	135	126	40	200-250
17	750	190	188	174	200	175-90
18	703	342	88	85	100	299, 327
19	729	202	154	150	200	170-200
20	692	101	62	37	50	70-90
21	780	171	165	165	50	165-171
22	707	280	84	69	50	78
23	720	342	117	93	200	85-93

The majority of these wells are included in the GWSI database retrieval (Table 3.4). The relatively high well yields shown in Table 2 and Figure 3 (i.e. wells 1-6) are associated with the Cave Springs water supply. Other wells distributed across the region northeast of Cave Springs (Figure 3.17) are affiliated with productive carbonate aquifers.

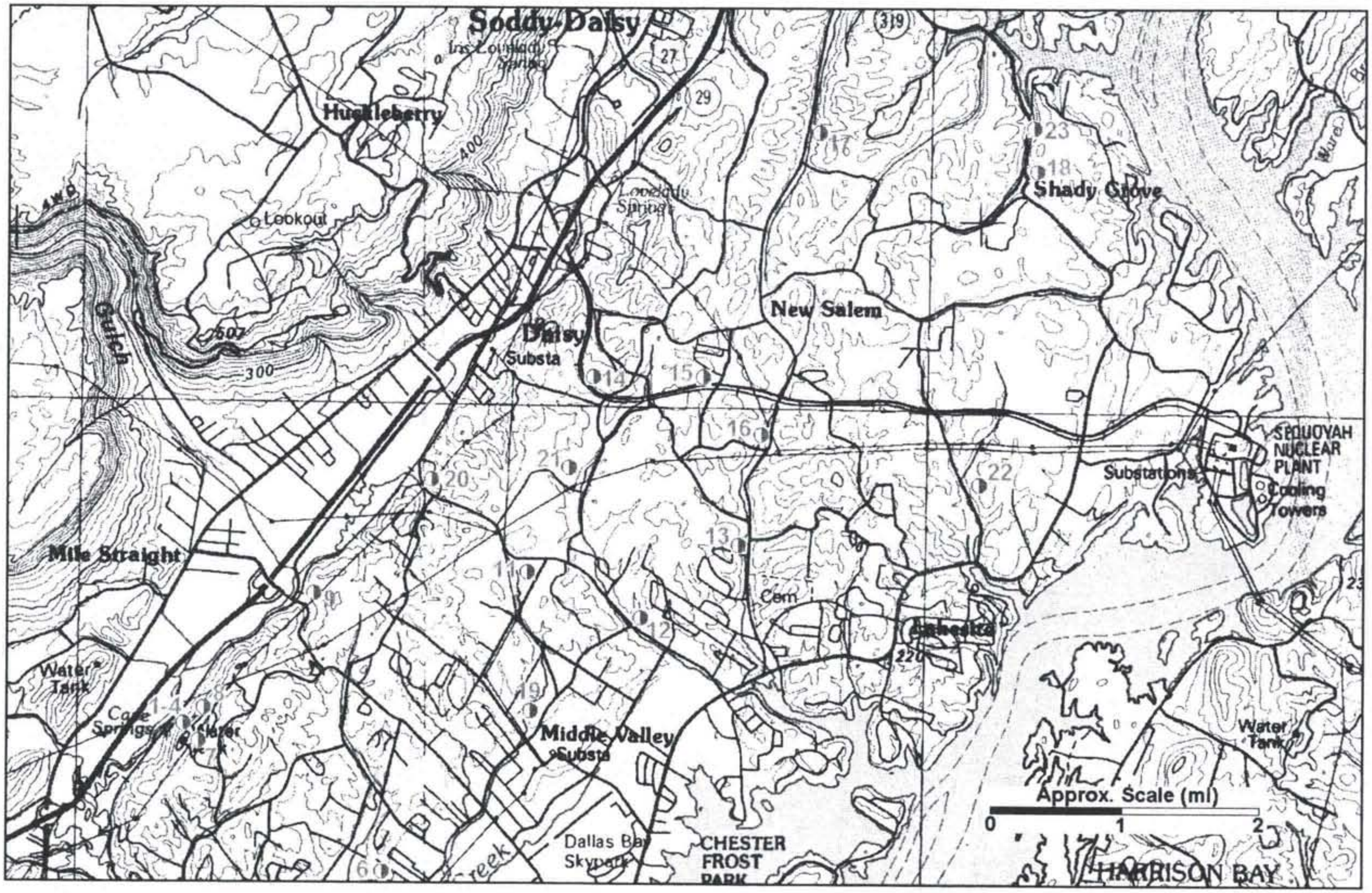


Figure 3.17 Groundwater Supply Wells in the Vicinity of SQN from Bradfield (1992)

3.7.2 Offsite Surface Water Supplies

As listed in Table 3.6, there are 23 surface water users within the 98.6-mile reach of the Tennessee River between Dayton, Tennessee and Stevenson, Alabama. These include fifteen industrial water supplies and eight public water supplies (TVA, 200*).

The public surface water supply intake (Savannah Valley Utility District), originally located across Chickamauga Reservoir from the plant site at TRM 483.6, has been removed. Savannah Valley Utility District has been converted to a ground water supply. The nearest public downstream intake is the East Side Utility (formerly referred to as U.S. Army, Volunteer Army Ammunition Plant). This intake is located at TRM 473.0.

Table 3.6 Public and Industrial Surface Water Supplies Withdrawn from 98.6 Mile Reach Of Tennessee River Between Dayton, TN and Stevenson, AL

Intake Name	Use (MGD)	Location	Approximate Distance from Site (River Miles)	Type Supply
City of Dayton	1.78	TRM 503.8 R	19.1 (Upstream)	Municipal
Cleveland Utilities Board	5.03	TRM 499.4 L Hiwassee RM 22.9	37.6 (Upstream)	Municipal
Bowaters Southern Paper	80.00	TRM 499.4 L Hiwassee RM 22.7	37.4 (Upstream)	Industrial & Potable
Hiwassee Utilities	3.00	TRM 499.4 L Hiwassee RM 22.5	37.2 (Upstream)	Municipal
Olin Corporation	5.00	TRM 499.4 L Hiwassee RM 22.3	37.0 (Upstream)	Industrial & Potable
Soddy-Daisy Falling Water U.D.	0.93	TRM 487.2 R Soddy Cr. 4.6 Plus 2 Wells	7.1 (Upstream)	Municipal
Sequoyah Nuclear Plant	1615.70	TRM 484.7 R	0.0	Industrial
East Side Utility	5.00	TRM 473.0 L	11.7 (Downstream)	Municipal
Chickamauga Dam	not measured	TRM 471.0	13.7 (Downstream)	Industrial
DuPont Company	7.20	TRM 469.9 R	14.8 (Downstream)	Industrial
Tennessee-American Water	40.90	TRM 465.3 L	19.4 (Downstream)	Municipal
Rock-Tennessee Mill	0.50	TRM 463.5 R	21.2 (Downstream)	Industrial
Dixie Sand and Gravel	0.04	TRM 463.2 R	21.5 (Downstream)	Industrial
Chattanooga Missouri Portland Cement	0.10	TRM 456.1 R	28.6 (Downstream)	Industrial
Signal Mountain Cement	2.80	TRM 454.2 R	30.5 (Downstream)	Industrial
Raccoon Mount. Pump Storage Project	0.56	TRM 444.7 L	40.0 (Downstream)	Industrial
Signal Mountain Cement	0.20	TRM 433.3 R	51.4 (Downstream)	Industrial
Nickajack Dam	not measured	TRM 424.7	60.0 (Downstream)	Industrial
South Pittsburg	0.90	TRM 418.0 R	66.7 (Downstream)	Municipal
Penn Dixie Cement	0.00001	TRM 417.1 R	67.6 (Downstream)	Industrial
Bridgeport	0.60	TRM 413.6 R	71.1 (Downstream)	Municipal
Widows Creek Stream Plant	397.40	TRM 407.7 R	77.0 (Downstream)	Industrial
Mead Corporation	4.40	TRM 405.2 R	79.5 (Downstream)	Industrial

R = Right River Bank, L = left River Bank

4.0 TRITIUM INVESTIGATION

Field investigations during this study focused largely on areas north and south of Units 1 and 2. Initial identification of areas for targeted investigations was based on information collected from the following sources:

- Preliminary site meetings with SQN staff;
- Previous tritium monitoring results associated with wells located along waste condensate lines;
- Historical tritium detection at other monitoring wells (e.g., W5 and W21);
- Preliminary assessments of inadvertent liquid radwaste releases;
- Relative locations of large/deep underground appurtenances;
- Potentially transmissive groundwater migration routes (e.g., pipeline bedding pathways).

The majority of tritium data collected from site groundwater monitoring prior to initiation of this investigation was available for review in spreadsheet format. Temporal and spatial examination of groundwater tritium concentrations data was conducted prior to field investigations. Reports documenting inadvertent liquid radwaste releases were made available by SQN staff. Hardcopy and electronic versions of essential site drawings were examined prior to and during field investigations. Key site features (e.g., underground lines and conduits) were electronically digitized and georeferenced imagery was developed using Geographic Information System (GIS) methods. Spatial data were incorporated into the GIS geodatabase with project progression. Several thousand large format (8 x 10 inch) photograph negatives (prepared during plant construction) were also examined at the National Archives Southeast Region Facility.

Preliminary results suggested that tritium sources might be associated with inadvertent liquid releases from the MFTDS, Unit 1 and 2 RWST, CDWE Building, and/or the Unit 2 Additional Equipment Building. Based on comparable tritium investigations completed at WBN (ARCADIS, 2004), and similarity of SQN plant design to WBN, the Unit 1 and 2 Auxiliary and Shield Buildings were included as potential tritium sources during this investigation. Major tasks associated with the field investigation included:

1. Sampling of selected existing wells;
2. Manual sampling of storm drain catch basins, vaults, and manholes;
3. Groundwater sampling using Geoprobe methods;
4. Manual and continuous water level monitoring;
5. Interior sampling at select locations.

4.1 Groundwater Sampling of Selected Existing Wells

Initial groundwater sampling for this study was targeted at site perimeter wells to confirm that offsite migration of tritium is not occurring. Fourteen existing wells were selected for sampling (Table 4.1). These wells are located along site boundaries and are not presently included in the routine groundwater monitoring network for tritium. Well locations are shown in Figure 1.2. This sampling event included three bedrock wells (W1, W2, W4), soil/bedrock well L6 at the LLRWSF, eight soil wells south of Unit 2 (14, 16, 20, 22, 30, 32, 34, 35), and two diesel extraction wells (EXT-2, EXT-4) located near the discharge.

Table 4.1 Tritium Results from Selected Existing Wells

Location	Diameter (in)	Top of Casing (ft-msl)	Top of Ground (ft-msl)	Depth from TOC (ft)	Bottom of Hole (ft-msl)	Sampling Date	Tritium Concentration (pCi/L)
W1	6	708.9	705.6	155.0	553.9	10/04/2006	< 270
W2	6	700.9	700.1	157.8	543.1	10/05/2006	< 270
W4	6	742.3	732.3	130.4	611.9	10/05/2006	< 270
L6	3	734.8	733.8	79.7	655.1	10/04/2006	< 270
14	2	707.9	705.2	18.8	689.1	10/06/2006	< 270
16	2	707.6	706.1	23.6	684.0	10/06/2006	< 270
20	2	697.9	697.9	23.1	674.8	10/05/2006	< 270
22	2	700.9	698.4	21.4	679.5	10/05/2006	< 270
30	1	707.2	704.1	23.8	683.4	10/06/2006	< 270
32	1	706.3	704.1	22.7	683.7	10/06/2006	< 270
34	1	708.1	704.8	25.7	682.5	10/06/2006	< 270
35	1	708.9	705.8	23.6	685.3	10/06/2006	< 270
EXT-2	12	702.2	700.0	26.0	676.2	10/06/2006	< 270
EXT-4	12	704.4	700.0	26.0	678.4	10/06/2006	< 270

Wells were purged and sampled October 4-6, 2006, using a combination of submersible pumps and disposable Teflon bailers. Samples were collected in 100 mL wide-mouth plastic sample containers and transferred to plant personnel for shipment to WARL for tritium analysis. Laboratory analysis indicated that tritium concentrations were less than the MDC of 270 pCi/L at all locations.

Perimeter well W5 has historically exhibited the presence of tritium but was not included in this sampling scheme since it is routinely monitored by SQN and WARL personnel through REMP.

4.2 Manual Sampling of Storm Drain Catch Basin, Vaults, and Manholes

Storm drain catch basins, vaults, and manholes were sampled to detect potential in-leakage of tritiated water from groundwater or discharge from plant processes. Sampling locations were initially identified using the following criteria: availability of water, depth (i.e., deep storm drain catch basins), accessibility, and proximity to the waste condensate lines and historical releases.

Twenty sites were selected (Table 4.2), including eighteen catch basins, the Turbine Building Sump Discharge, and a TV box sump. Sample locations are shown in Figure 4.1. All locations selected for sampling were within several hundred feet of the Reactor Buildings.

Table 4.2 Tritium Results from Manual Sampling Event

Location	Type	Depth to Invert (ft)	Depth to Water (ft)	Sampling Date	Tritium Concentration (pCi/L)
SS-1	Catch Basin	4.96	4.69	10/13/2006	< 270
SS-2	Catch Basin	5.10	5.03	10/13/2006	< 270
SS-3	Catch Basin	2.70	2.59	10/13/2006	< 270
SS-4	Catch Basin	5.10	5.00	10/13/2006	< 270
SS-5	Catch Basin	3.77	3.74	10/13/2006	< 270
SS-6	Catch Basin	2.61	2.61	10/13/2006	8,879
SS-7	Catch Basin	4.29	3.99	10/13/2006	< 270
SS-9	Catch Basin	5.03	4.99	10/13/2006	< 270
SS-10	Catch Basin	6.37	6.10	10/13/2006	< 270
SS-11	Catch Basin	8.31	8.07	10/13/2006	< 270
SS-12	Catch Basin	8.06	7.52	10/13/2006	< 270
SS-13	Catch Basin	2.05	2.04	10/13/2006	< 270
SS-14	Catch Basin	1.93	1.82	10/13/2006	425
SS-15	Turbine Building Sump	N/A		10/13/2006	< 270
SS-16	Catch Basin	3.46	3.39	10/13/2006	< 270
SS-17	Catch Basin	12.59	12.40	10/13/2006	< 270
SS-18	Catch Basin	10.18	9.84	10/13/2006	< 270
SS-19	Catch Basin	3.70	3.61	10/13/2006	< 270
SS-21	TV Box Sump	2.56	1.78	10/13/2006	284
SS-22	Catch Basin	7.80	7.59	10/13/2006	312

Samples were collected October 13 by dropping a sponge (on a string) through the catch basin grating to soak up water, retrieving it, and then wringing it into a 100 mL wide-mouth plastic sample container. Sponge and string were disposed of after each location sampled. The outside of the sampling containers were thoroughly rinsed to remove any trace of overflow. Depth-to-water and depth-to-invert were measured after sampling using an electronic water level meter, and the water level meter was decontaminated between locations. Sample containers were transferred to SQN personnel, then transported to WARL for tritium analysis.

Table 4.2 summarizes sampling results. Tritium was observed at catch basin locations SS-6 (8,879 pCi/L), SS-14 (425 pCi/L), SS-21 (284 pCi/L), and SS-22 (312 pCi/L). All other samples were less than the MDC.

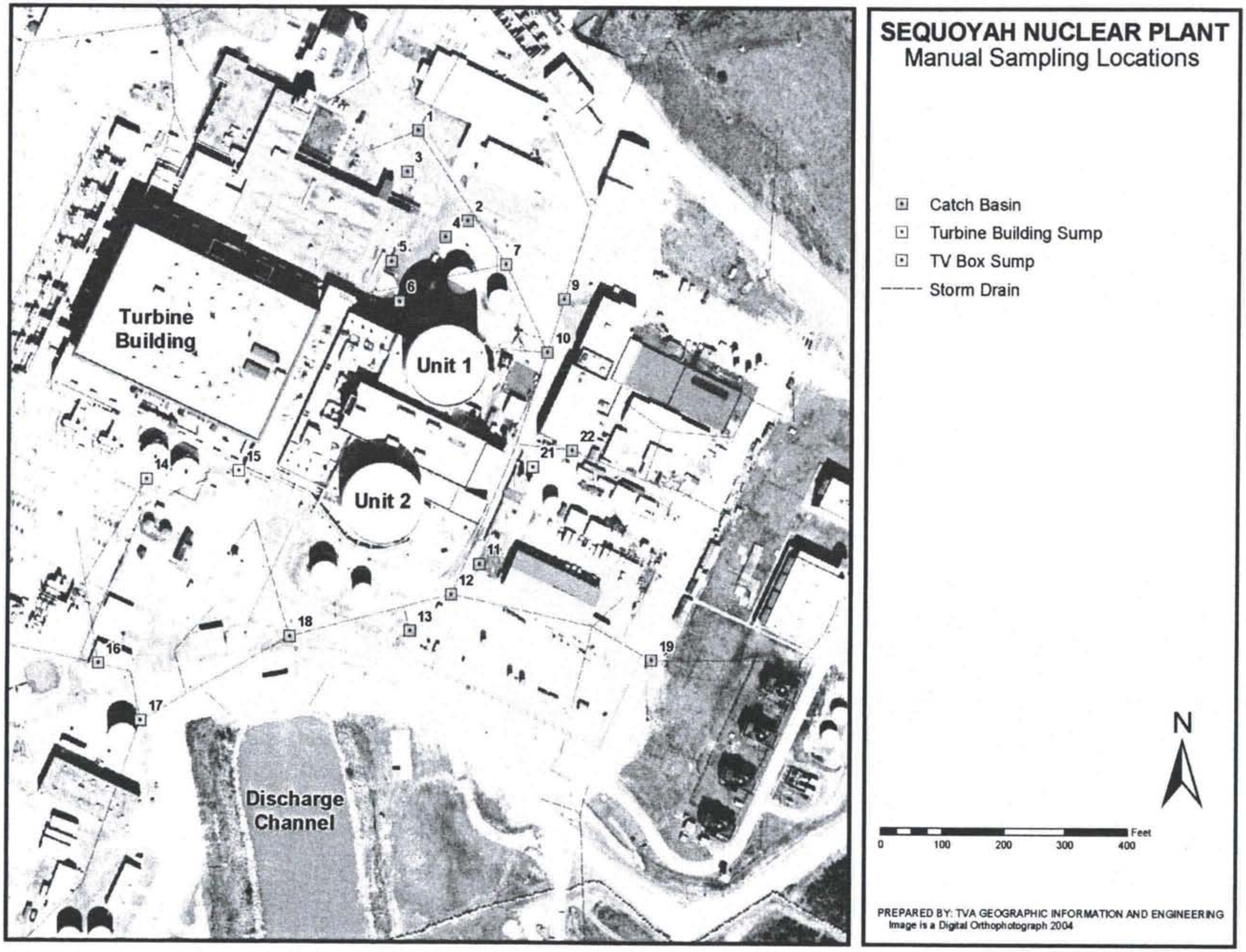


Figure 4.1 Map of Manual Sampling Locations

4.3 Groundwater Sampling using Geoprobe Methods

Groundwater sampling using a Geoprobe allows sampling rods to be "pushed" into the ground without the use of drilling and produces minimal investigation-derived waste. The Geoprobe direct-push machine relies on a relatively small amount of static (vehicle) weight combined with percussion as the energy for advancement of a tool string. The Geoprobe offers a significant safety advantage since the probe tends to resist on concrete and steel pipelines, and downholes tools are easily decontaminated between borings.

Thirty-one (31) Geoprobe boring locations were initially identified at the site based on the existing knowledge of groundwater movement and the relative locations of major underground lines and appurtenances (e.g., ERCW lines and intake conduits). Bedding materials surrounding underground lines represent potential preferential pathways for subsurface movement of groundwater contaminants; therefore, these features were a consideration of the investigation. Site design and as-built drawings of underground utilities were reviewed in relation to proposed boring locations to avoid potential drilling conflicts. For final verification of proposed boring locations, a radio frequency utility location investigation was conducted under contract with Underground Locators of Nashville, Inc, during November 2006. The utility location survey evaluated potential utilities and metallic obstructions around the areas of the field-staked boring locations. The boring locations were offset if direct obstructions were identified to provide a minimum horizontal clearance of the 2-ft locate variation in all directions.

Sampling of groundwater using Geoprobe methods was conducted during January and February 2007. Due to subsurface resistance at many locations (i.e., concrete), groundwater samples were ultimately collected at 23 locations (Figure 4.2; Table 4.3). When possible, groundwater samples were collected in situ (from within the Geoprobe push-rod at depth) using a 0.5-inch OD stainless steel bailer or were siphoned using Teflon tubing. Where groundwater recovery rates were slow, temporary 0.5-inch ID screen and casing were installed and samples were collected using a 0.5-inch OD stainless steel bailer or were siphoned using Teflon tubing. All temporary well materials were discarded after a single use; although, in some cases, Teflon tubing was reused after being decontaminated between samples. Groundwater samples were transferred to 100 mL wide-mouth plastic sample containers, and turned over to plant personnel to transmit to WARL for tritium analysis. Decontamination involved scrubbing downhole equipment with a distilled water/laboratory detergent mix and rinsing with distilled water.

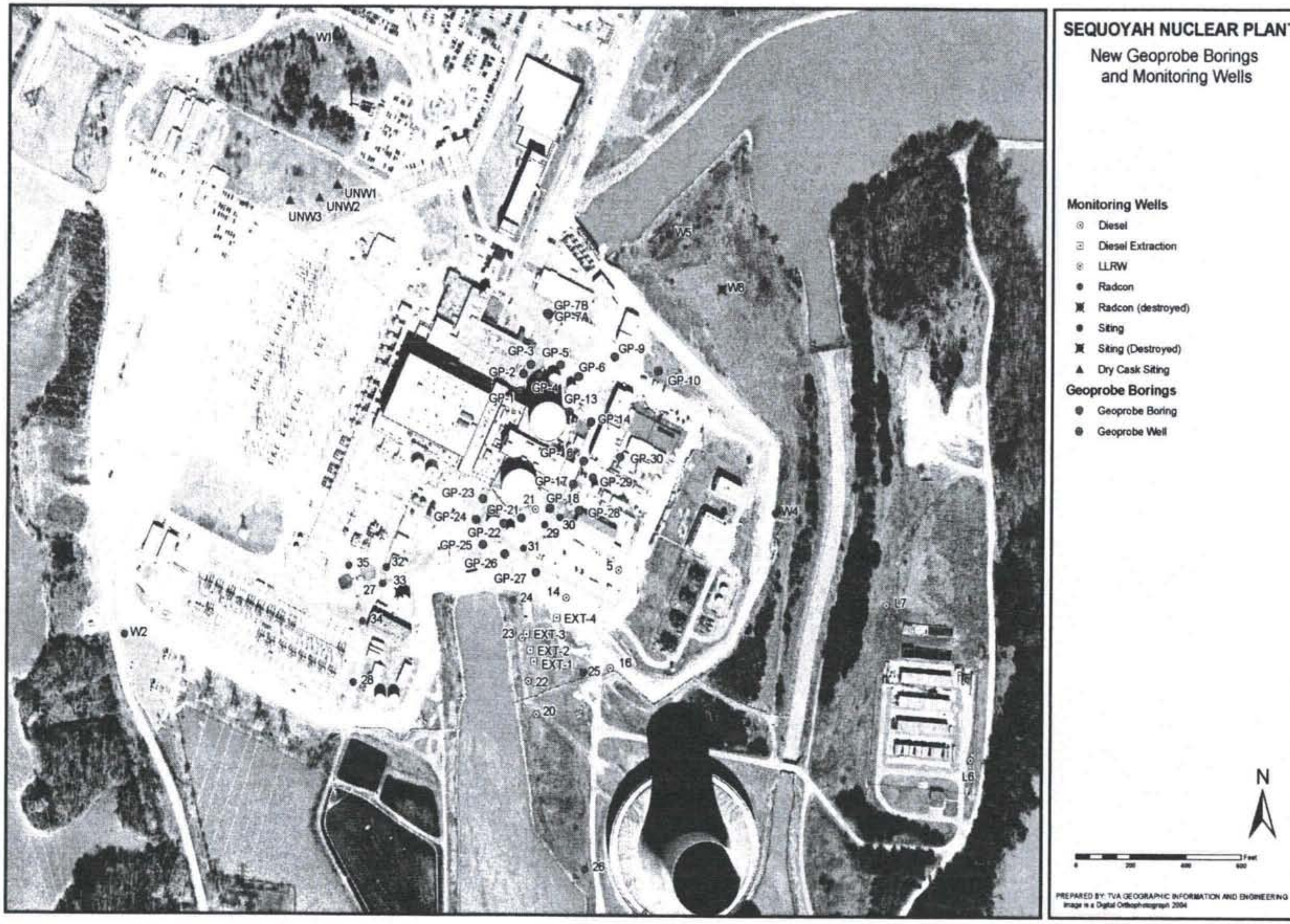


Figure 4.2 Map Showing Geoprobe Sampling Locations and Monitoring Wells

Figure 4.3 provides a profile of Geoprobe borings installed during the investigation. Five of the borings were completed as 1-inch monitoring wells to supplement groundwater level measurements in areas lacking groundwater level information. These wells include GP-7A, GP-7B, GP-10, GP-13, and GP-24 (Figure 4.2). Well diagrams are provided in Appendix A.

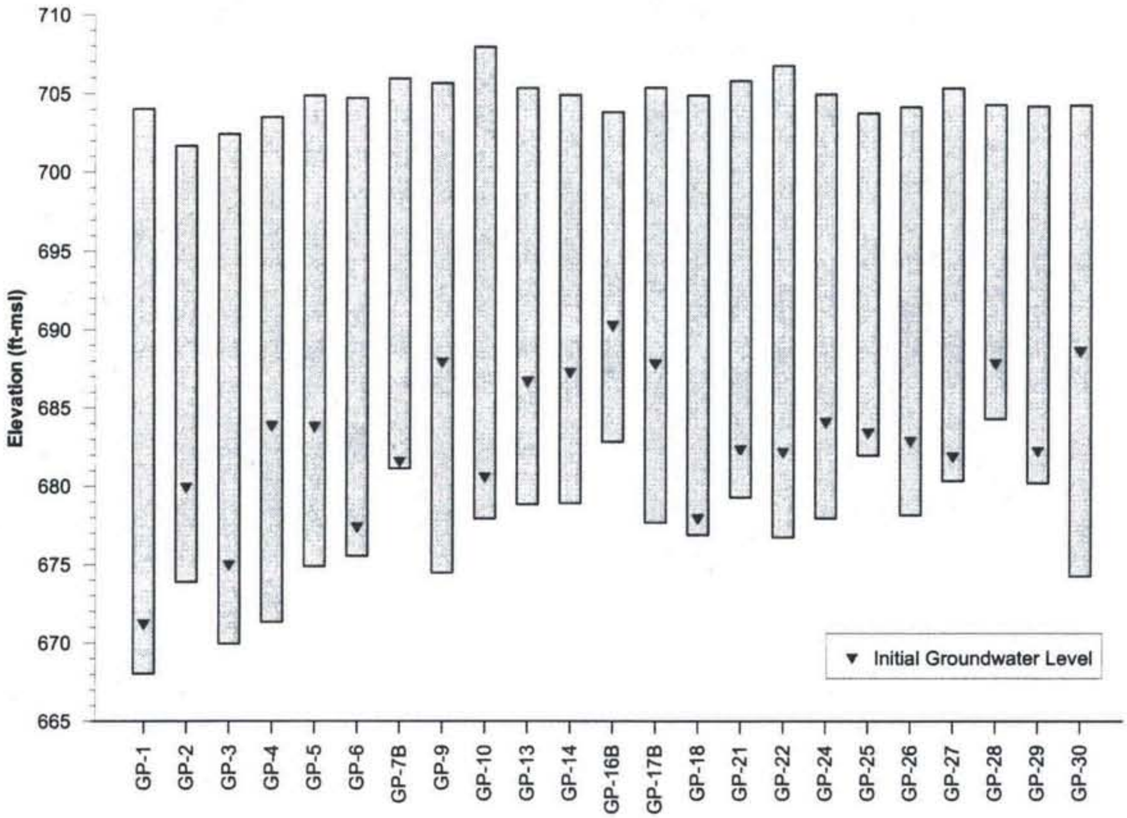


Figure 4.3 Profile of Geoprobe Borings

Table 4.3 provides a summary of groundwater sampling locations and analytical results from Geoprobe investigations. As indicated, tritium was observed at low concentrations in borings (GP-1 – GP-7) near the Unit 1 RWST, in borings S-SE of Unit 2 (GP-21, GP-22, GP-25, GP-26), and at GP-28. The highest tritium concentration observed in Geoprobe borings occurred at GP-13 (16, 211 pCi/L).

Table 4.3 Tritium Results from Geoprobe Sampling

Location	Top of Ground (ft-msl)	Depth (ft)	Bottom of Hole (ft-msl)	TN NAD27 (ft) Easting	Northing	Sampling Date	Tritium Concentration (pCi/L)
GP-1	704.1	36.0	668.1	2271360.0	305170.7	1/26/2007	274
GP-2	701.7	27.8	673.9	2271373.9	305226.7	1/29/2007	733
GP-3	702.4	32.5	669.9	2271401.2	305258.6	1/25/2007	623
GP-4	703.5	32.2	671.3	2271433.3	305221.2	1/30/2007	661
GP-5	704.9	30.0	674.9	2271510.6	305256.8	1/25/2007	420
GP-6	704.7	29.2	675.5	2271575.9	305218.7	1/25/2007	306
GP-7B	705.9	24.8	681.1	2271461.1	305425.8	2/12/2007	394
GP-9	705.7	31.2	674.5	2271708.1	305284.7	1/31/2007	< 270
GP-10	707.9	30.0	677.9	2271366.7	305237.9	2/01/2007	< 270
GP-13	705.3	26.5	678.8	2271543.4	305102.4	2/01/2007	16,211
GP-14	704.9	26.0	678.9	2271621.5	305069.1	2/05/2007	< 270
GP-16B	703.8	21.0	682.8	2271594.8	304938.8	2/15/2007	< 270
GP-17B	705.4	27.7	677.7	2271558.3	304862.1	2/16/2007	< 270
GP-18	704.9	28.0	676.9	2271476.6	304781.9	2/06/2007	< 270
GP-21	705.8	26.5	679.3	2271368.9	304750.0	2/06/2007	750
GP-22	706.7	30.0	676.7	2271304.2	304732.2	2/07/2007	2,700
GP-24	704.9	27.0	677.9	2271204.3	304744.0	2/07/2007	< 270
GP-25	703.8	21.8	682.0	2271230.4	304662.1	2/07/2007	874
GP-26	704.1	26.0	678.1	2271309.7	304630.9	2/07/2007	332
GP-27	705.3	25.0	680.3	2271425.5	304571.1	2/12/2007	< 270
GP-28	704.3	20.0	684.3	2271580.9	304774.2	2/13/2007	394
GP-29	704.2	24.0	680.2	2271629.2	304884.0	2/13/2007	< 270
GP-30	704.2	30.0	674.2	2271730.8	304953.5	2/13/2007	< 270

4.4 Water Level Monitoring

Groundwater level monitoring at the site during this investigation included manual measurements at existing wells and new wells in close proximity to the plant site on approximately a monthly basis beginning December 13, 2006. Continuous water level and temperature monitoring was conducted at three selected wells (14, W21, and GP-13) and at the head of the Discharge Channel. Solinst (Model 3001) downhole dataloggers were deployed (beginning 11/17/06) for continuous monitoring of water levels and temperatures. Continuous (hourly) surface water levels are collected for Chickamauga Reservoir on the southeast corner of the Intake Channel Skimmer Wall (Figure 1.1) at TRM 484.8.

Results from pre-investigation water level monitoring were coupled with recent data. Figure 4.4 depicts time-series groundwater levels for wells W21, 29, 30, and 31 in the vicinity of Unit 2. As shown in the figure, groundwater gradients are consistent with time and all groundwater levels are influenced by operation of the Chickamauga Reservoir and the Discharge Channel (see Section 3.3). That is, under normal operations, water elevation begins to increase in April and recession begins in September. The maximum range of groundwater levels over this 3-year interval is 9.7 ft (wells W21 and 31). Groundwater levels at wells 29 and 30 fluctuated over < 6.0 ft for this period. Apparent in Figure 4.4 is the excellent degree of correlation in groundwater levels at wells W21 and 31.

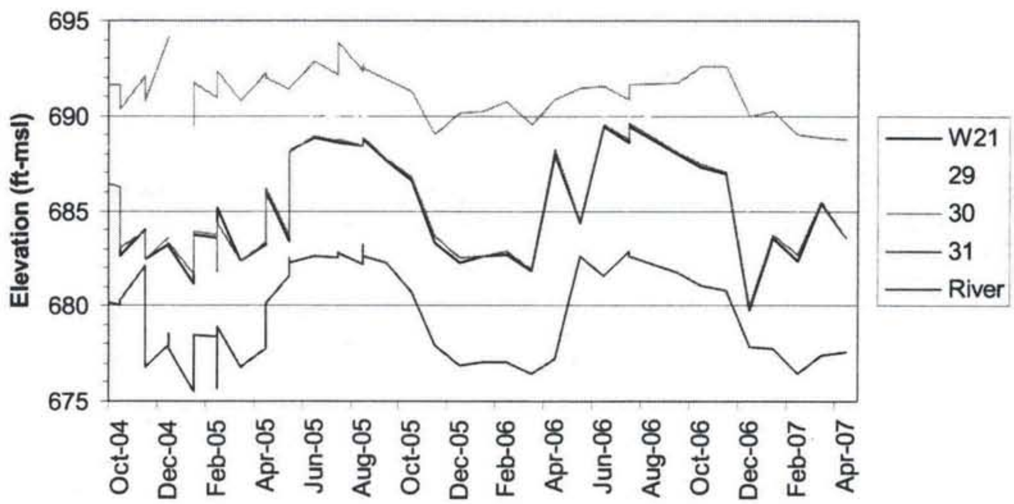


Figure 4.4 Time-Series Water Levels at Wells W-21, 29, 30, 31 and the River

Figure 4.5 shows time-series groundwater levels for RadCon wells in the vicinity of the 12-inch Waste Condensate Line. Although these wells are located at similar distances from the Discharge Channel, groundwater levels are not correlated with surface water elevations. However, correlation in groundwater levels among these wells is evident. Compared to wells nearer Unit 2, the maximum range of groundwater levels over this 3-year interval was 13.1 ft (well 34). Groundwater levels at wells 27 and 33 fluctuated over <5.0 ft for this period.

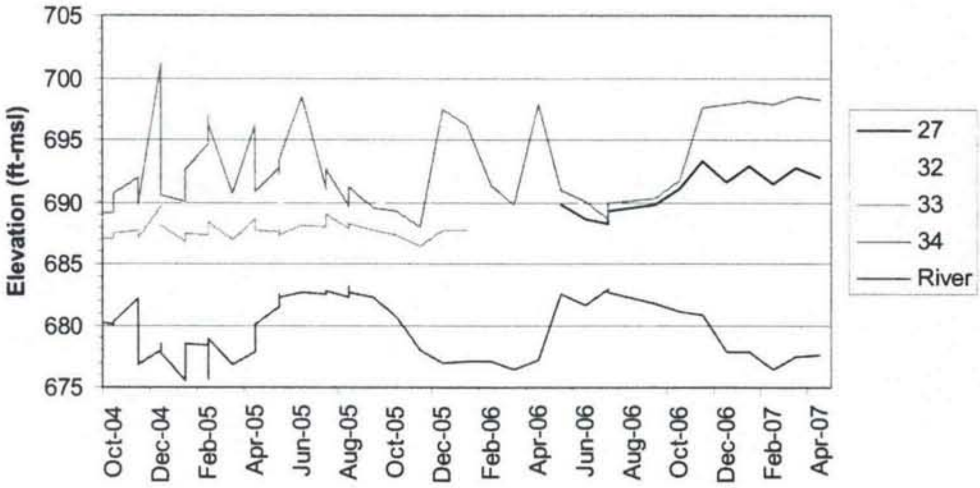
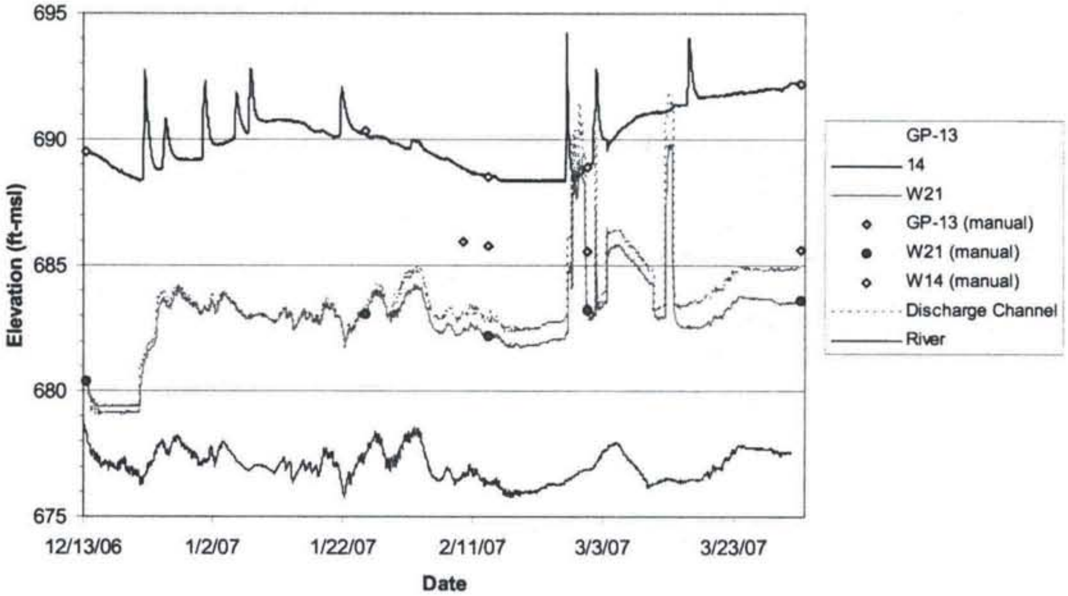


Figure 4.5 Time-Series Water Levels at Wells 27, 32, 33, 34 and the River

Continuous temperature and water level data collected for this investigation are presented in Figure 4.6. The most obvious feature in this figure is correspondence of water levels between well W21 and the Discharge Channel. Timing and magnitude of water level changes match exceedingly well. The continuous water level data are too coarse to allow exact time-matching between these two locations (i.e., measurements frequency was hourly at W21 and 20 minutes at the channel). However, data is sufficient to indicate that well W21 responds to changes in Discharge Channel water levels in less than two hours. Noting that well W21 is located 285 ft from the head of the Discharge Channel, hydraulic pressure changes via natural porous media at the site would not produce these types of responses. Results indicate the presence of a subsurface feature(s) residing at depth (<679 ft-msl) providing relatively direct connection between these two locations. Given the correlation in groundwater levels between wells W21 and 31 (Figure 4.4), this or another feature(s) also extends to the vicinity of well 31 (145 ft from the head of the channel).

Figure 4.7 presents continuous water level data at wells W21, 14, and the Discharge Channel for the interval 11/17/06 – 01/24/07. Of interest in this figure is the precipitous change in well W21 groundwater levels coincident with the beginning and ending of the plant outage from 11/26/06 – 12/24/06. Also noted is the anomalous departure of correlation between well W21 and the Discharge Channel from 12/05/06 – 12/15/06 during the outage interval. Daily operations log entries were examined in attempts to identify any major water transfers that might be associated with rapid changes in groundwater levels (e.g., RWST and Spent Fuel Pool transfers). There is no evidence of changes in groundwater levels associated with such transfers.



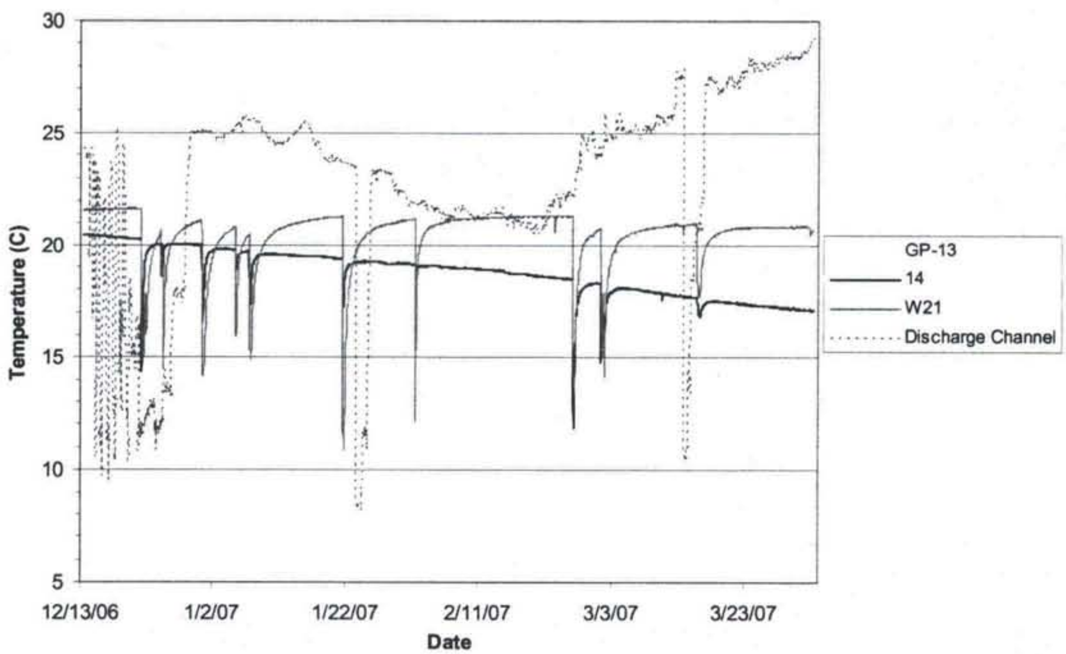


Figure 4.6 Continuous Water Levels (Top) and Temperatures (Bottom) at Wells GP-13, 14, W21, the Discharge Channel, and the River

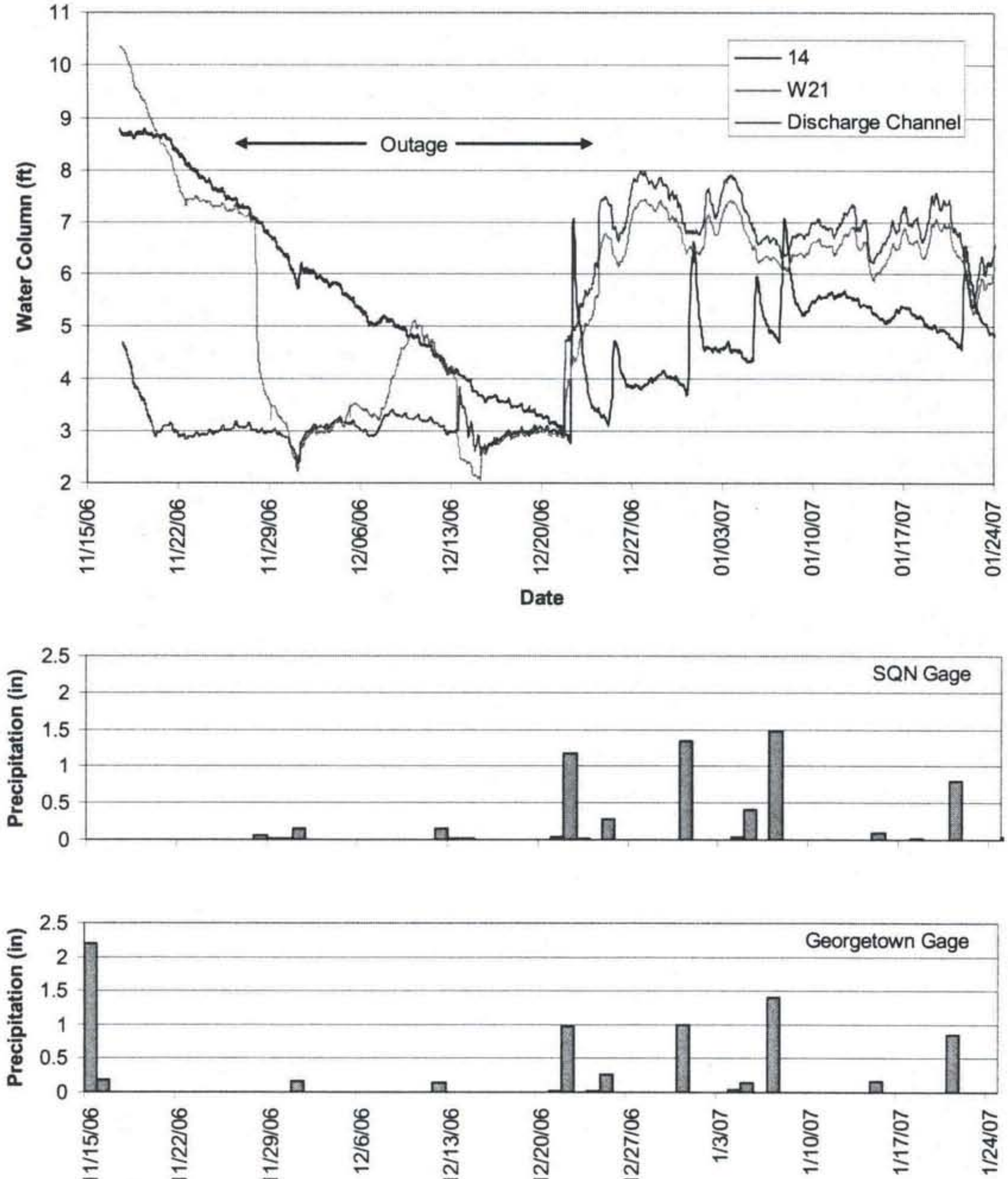


Figure 4.7 Continuous Water Levels (Top) and Precipitation (Bottom) at Wells 14, W21, and the Discharge Channel

Well 14 experiences abrupt weekly to biweekly groundwater level increases (Figures 4.6 and 4.7) over most of the monitoring period. The water level changes are correlated with pronounced water temperature decreases (Figure 4.6). Precipitation data from the plant meteorological station and from the Georgetown gage (9 miles NE of SQN) were obtained and are shown at the bottom of Figure 4.7. As shown, groundwater level and temperature changes at well 14 are clearly linked with rainfall events. It is highly probable that the well 14 wellhead seal has been damaged and that rainfall runoff is directly entering the well annulus at this location. Similar results are observed in temperature data at well W21. Again, data suggests that well W21 wellhead seal has been damaged.

Figure 4.8 depicts the potentiometric surface at the site based on April 02, 2007 groundwater level measurements. Groundwater movement is northerly over the Unit 1 portion of the site with the Intake Channel serving as a primary surface water control to hydraulic gradients. Over the Unit 2 side of the site, groundwater movement is primarily southerly with convergent flow toward the Discharge Channel.

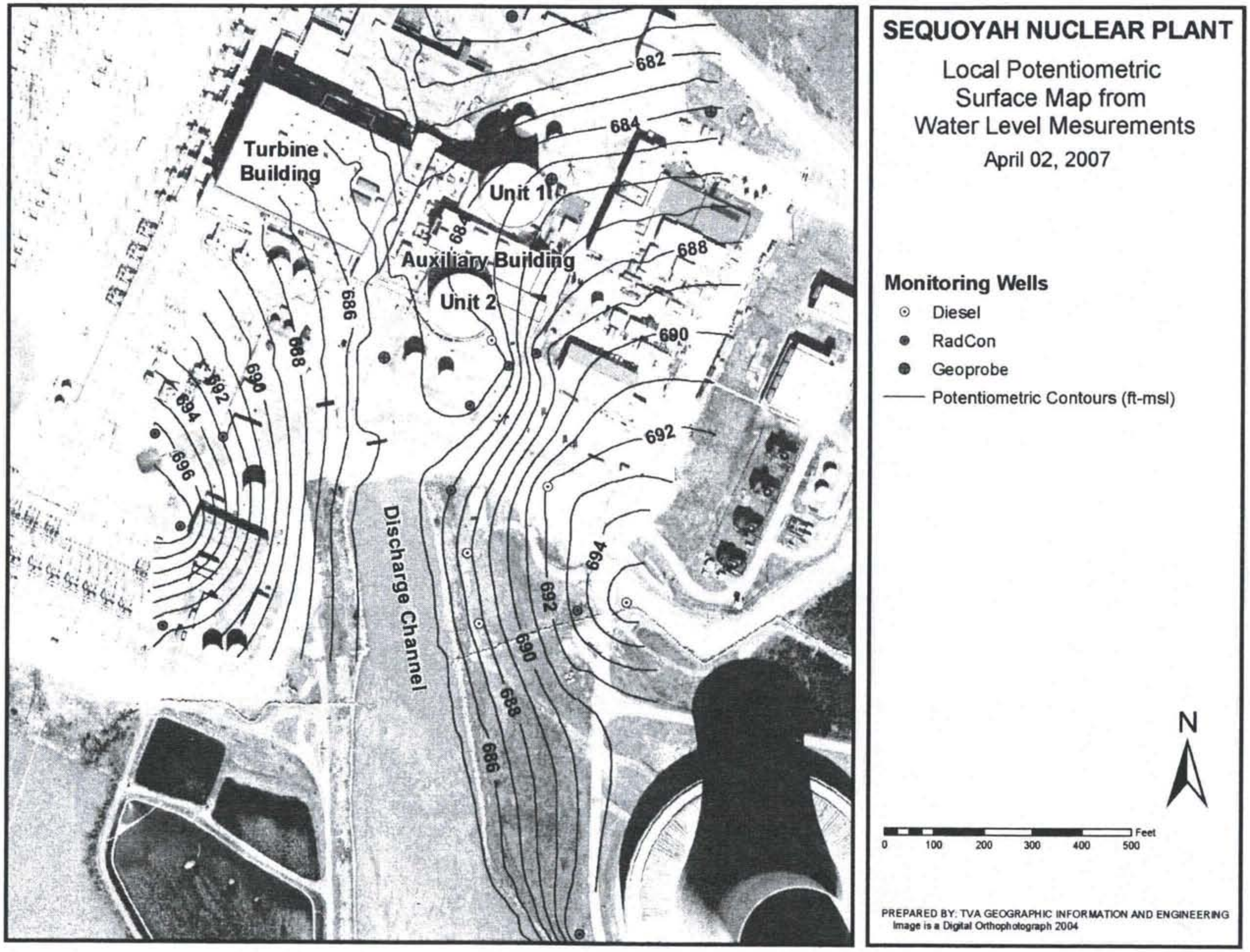


Figure 4.8 Local Potentiometric Surface from April 02, 2007 Water Level Measurements

4.5 Interior Sampling

Groundwater inleakage occurs at SQN along concrete construction joints, poorly sealed pipe sleeves, concrete factures, and other locations. During this investigation, several areas were visually inspected and groundwater inleakage samples were collected for tritium analyses. Inspection locations were selected based on historical observations of seepage, depth, and location (i.e., below groundwater table and in vicinity of observed tritium), and accessibility. Locations identified for inspections and sampling included the Auxiliary Building, north wall of the Turbine Building, and RWST pipe tunnels for both units.

Groundwater inleakage has been documented at SQN since 1978 (TVA, 1978). At this time, groundwater inleakage was described in the Auxiliary Building. At the request of SQN, an inspection of the Auxiliary Building inleakage problem was performed by J. M. Boggs of TVA's Engineering Laboratory during May 1997. Inleakage locations were identified on plant drawings and catalogued with photographs (Figure 4.9).

As shown in Figure 4.9, twelve inleakage locations have been identified in the Auxiliary Building at floor elevations 653 and 669 ft-msl. Red symbols identified locations where inleakage rates were sufficiently high in 1997 to require collection. Blue symbols identified locations of low inleakage rates not requiring collection. These locations are listed in Table 4.4. Two additional inleakage locations not identified in Figure 4.9 and Table 4.4 were documented (1997) at a leaking conduit in the Unit 1 UHI pit and at a 4-inch diameter pipe sleeve near elevation 655 ft-msl of the UHI pit.

Table 4.4 Auxiliary Building Groundwater Inleakage Locations

Location	Remarks
1	Elevation 653 ft-msl pipe chase, high inleakage rate
2	Seepage being collected, moderate inleakage rate
3	Two inleakage locations, drip funnels being used for collection
4	no comment
5	no comment
6	Leak at concrete construction joint
7	Leak above floor in wall
8	Patched
9	Leak at floor
10	no comment
11	no comment

Sampling of groundwater inleakage from the north wall of the Turbine Building (near elevation 662 ft-msl) was conducted on 10/20/06. Analysis by WARL indicated that tritium was less than the MDC of 220 pCi/L.

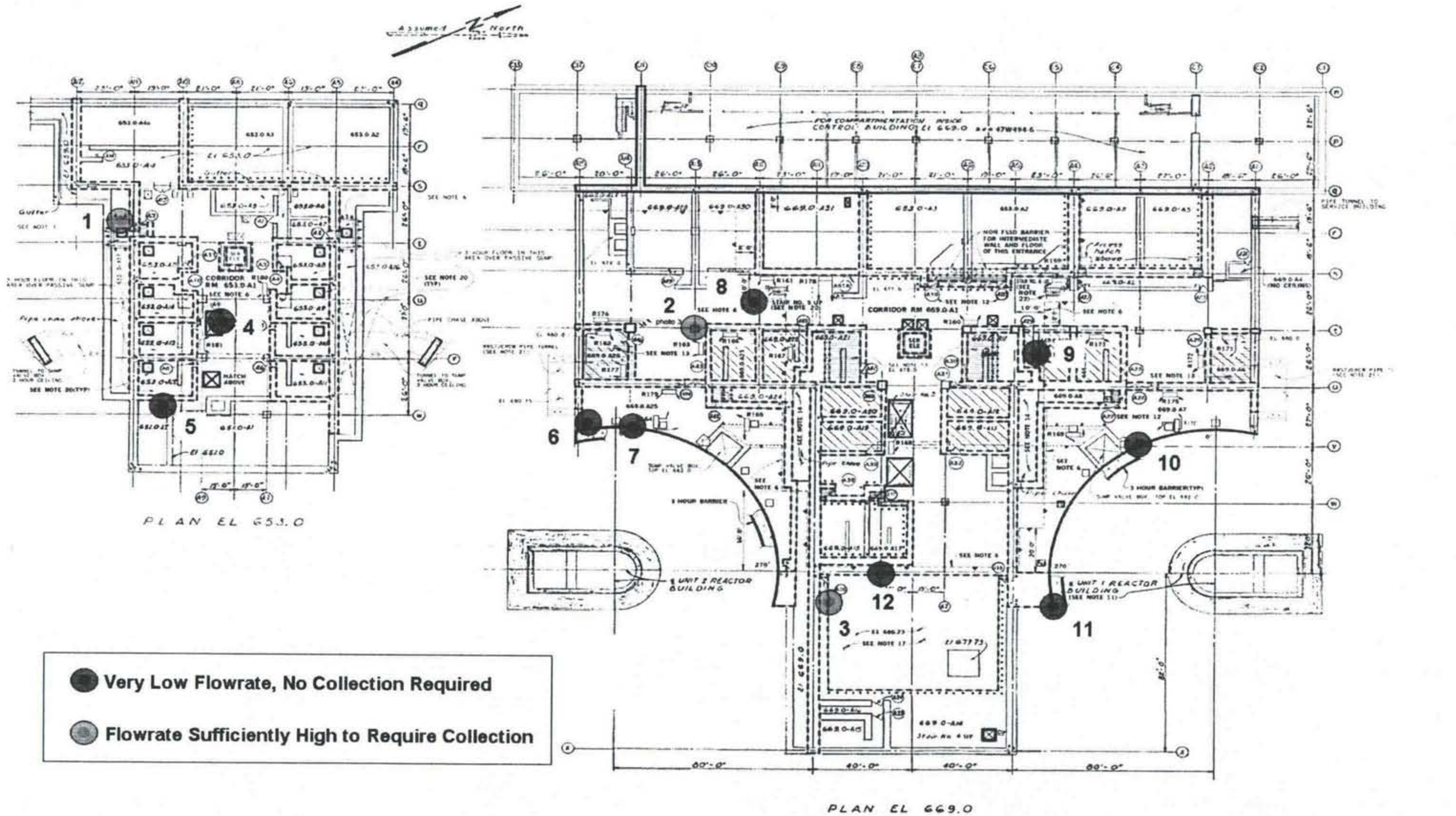


Figure 4.9 Groundwater Inleakage Locations at Auxiliary Building

Inspection and sampling within the Unit 1 and 2 RWST pipe tunnels was performed by SQN staff under work orders 06-776301-000 and 06-776302-000 during 8/28/06 and 8/31/06. Groundwater inleakage samples were collected from tunnel walls and water samples were collected from trough drains at each location. Analyses by WARL indicated that tritium was less than the MDC of 220 pCi/L for all samples.

Based on comparable tritium investigations completed at WBN, and similarity of SQN plant design to WBN, inspection of Unit 1 and 2 Annuli and transfer tube bellows are being performed by SQN staff. These inspections involve boroscope methods and removal of concrete block shield walls for access. Where possible, samples are being collected for analyses. These investigations are continuing and results are forthcoming.

5.0 RESULTS AND RECOMMENDATIONS

5.1 Tritium Distribution

5.1.1 Manual Sampling

Manual sampling at 20 catch basins, vaults, and manholes (Figure 4.1; Table 4.2) during this study showed positive detection of tritium at four shallow locations. The sampling depths at these locations were >15 ft above the groundwater table. Tritium was observed at SS-6 (8,879 pCi/L), SS-14 (425 pCi/L), SS-21 (284 pCi/L), and SS-22 (312 pCi/L). All other samples were less than the MDC.

Observation of tritium in catch basin SS-6 (2.6 ft deep) near the Service Building is not completely explicable. The observed tritium concentration is an order of magnitude greater that tritium concentrations observed in groundwater from Geoprobe borings (GP-1 – GP-4) in the immediate vicinity. Results suggest that the observed tritium concentration might be associated with direct discharges to the single line entering this catch basin.

The low tritium concentration at catch basin SS-14 (1.9-ft deep), near the 12-inch waste condensate line, is similar to tritium concentrations observed for soil wells located along the condensate line. The 12-inch condensate line is located above ground at this location and leaks to ground surface could produce the observed concentration. Likewise, overflows from the Turbine Building sump could produce similar results.

The low tritium concentration observed at catch basin SS-22 (7.8 ft deep) may be the result of a release from the MFTDS (Section 2.3) that occurred in 1997. A correspondingly low tritium concentration at the SS-21 TV box sump (2.6-ft deep) may also be the results of the MFTDS release. However, this vault possesses an impermeable cover. It is conceivable that the source of tritiated water within the SS-21 sump is associated with contaminated groundwater some distance upgradient (west) of the electrical vaults. Electrical conduits (and their bedding materials) intersecting such vaults are probable avenues for shallow groundwater transport.

Manual sampling of several selected locations was performed during January 2004 to support siting of RadCon wells located along 12-inch waste condensate line. Water sampling results at all locations indicated tritium concentrations <MDC of 220 pCi/L. Sampling locations included:

- Diesel Fuel Oil Interceptor Trench discharge;
- Turbine Building sump;
- Low-Volume Waste Treatment Pond inlet;
- Condensate water discharge from Turbine Building roof to sump;
- CO_2 vault sump south of Turbine Building;
- Alum Sludge Ponds A (west) and B (east);

- Water Treatment Plant basement sump;
- Storm drain #45 north of High Pressure Fire Protection System tanks;
- Storm drain #44 east of Water Treatment Plant;
- Storm drain #46 south of Unit 2 Condensate Storage Tanks.

5.1.2 Groundwater Sampling

From 1998 through 2001, tritium was consistently observed at concentrations ranging from 401 to 2,120 pCi/L at well W5 (Figure 1.2). No further tritium detection has been observed at well W5 since 2001. Beginning in February 2002, TVA expanded REMP groundwater monitoring at SQN (Section 1.3) with the addition of 12 soil monitoring wells and collection of groundwater samples from existing wells in proximity to known areas of tritium contamination. Since August 2003, 206 groundwater sampling events have been conducted at one or more of these wells. Tritium concentrations observed from these sampling events are tabulated in Appendix B.

As shown in Appendix B, tritium concentrations measured at wells 24-28, 30, and 32-35 have been <MDC with only a few exceptions near the MDC. Relatively high tritium concentrations (2,576 – 19,750 pCi/L) have been continuously observed at well 31 since May 2004. As shown in Figure 5.1 tritium concentrations are generally correlated with groundwater levels at well 31.

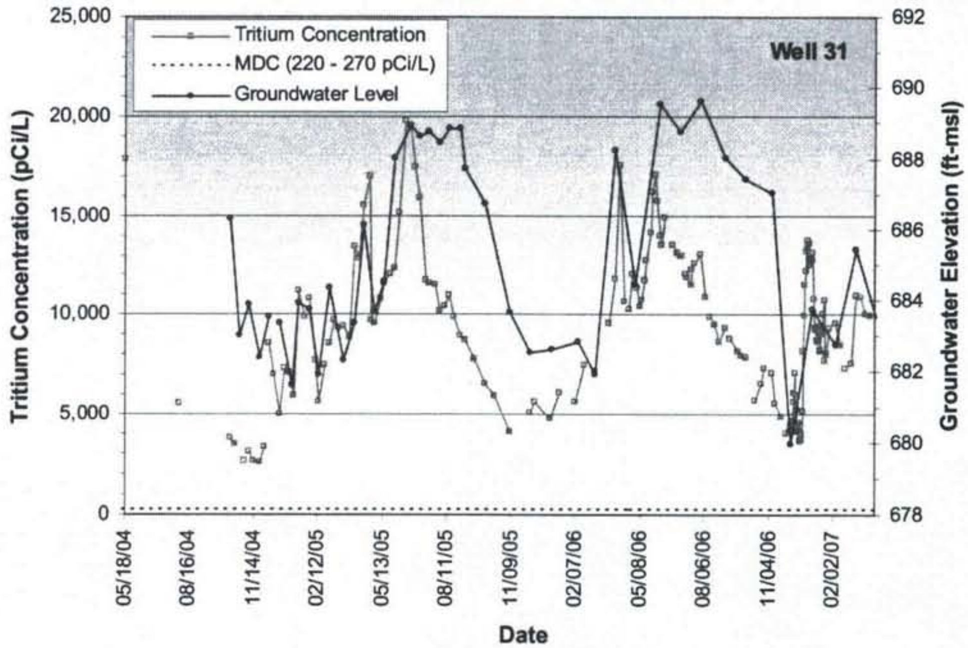


Figure 5.1 Time-Series Tritium Concentrations and Groundwater Levels at Well 31

At well W21, tritium concentrations have ranged from 226 – 9080 pCi/L since sampling commenced in February 2004. As shown in Figure 5.2, there is no correlation between tritium concentrations and groundwater levels at well W21. Low tritium concentrations have also been consistently observed at well 27 (<500 pCi/L) and well 29 (<1800 pCi/L) with no relationships between tritium and groundwater levels at either location (Figure 5.3).

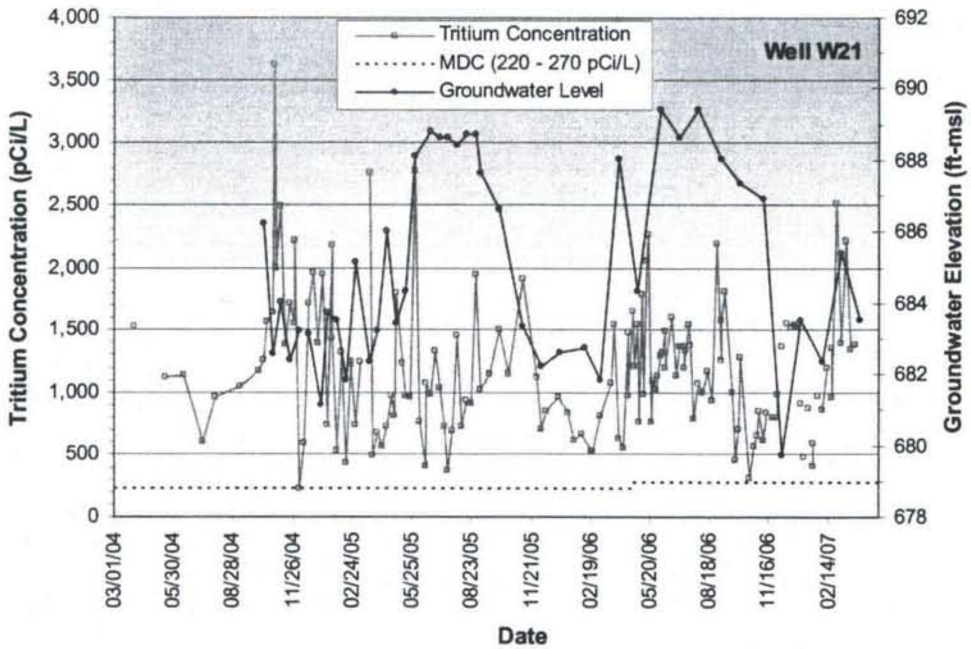
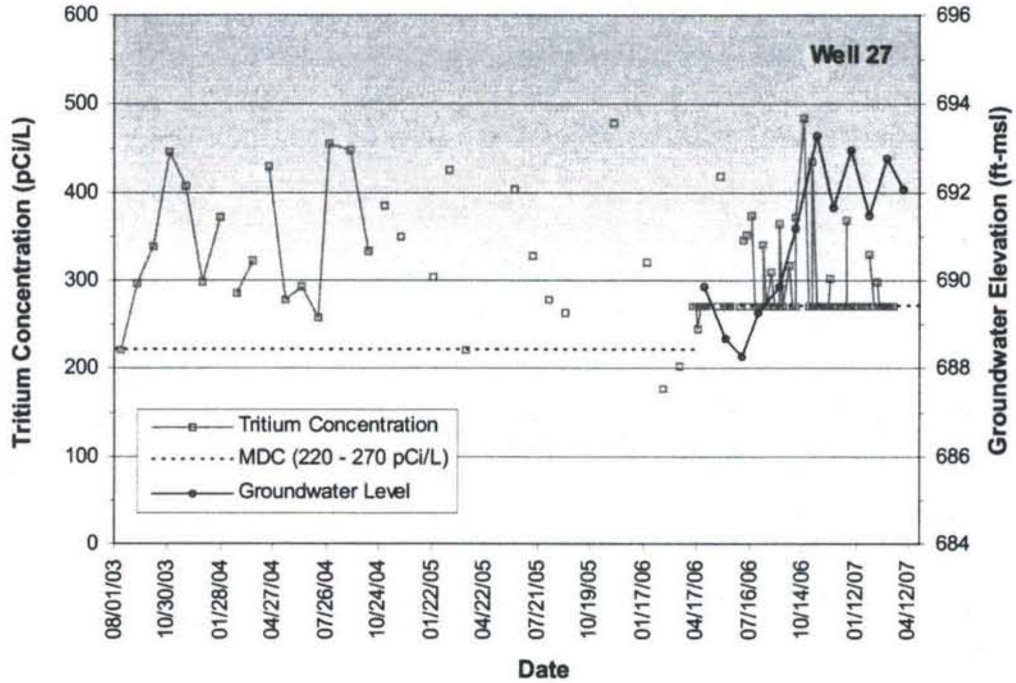


Figure 5.2 Time-Series Tritium Concentrations and Groundwater Levels at Well W21

Groundwater sampling at 23 Geoprobe borings (Figure 4.2; Table 4.3) indicated low tritium concentrations (274 – 661 pCi/L) in borings (GP-1 – GP-7) surrounding the Unit 1 RWST. Borings GP-21, GP-22, GP-25, and GP-26 exhibited low tritium concentrations (332 – 2700 pCi/L) in the area S-SE of Unit 2. Boring GP-28, just east of this area, provided a similarly low tritium concentration (394 pCi/L). The highest tritium concentration observed within all Geoprobe borings occurred at GP-13 (16, 211 pCi/L). Due to the relatively high groundwater tritium concentration at GP-13, a soil monitoring well was installed at this location and additional groundwater sampling was conducted. Figure 5.4 depicts sampling results to date.



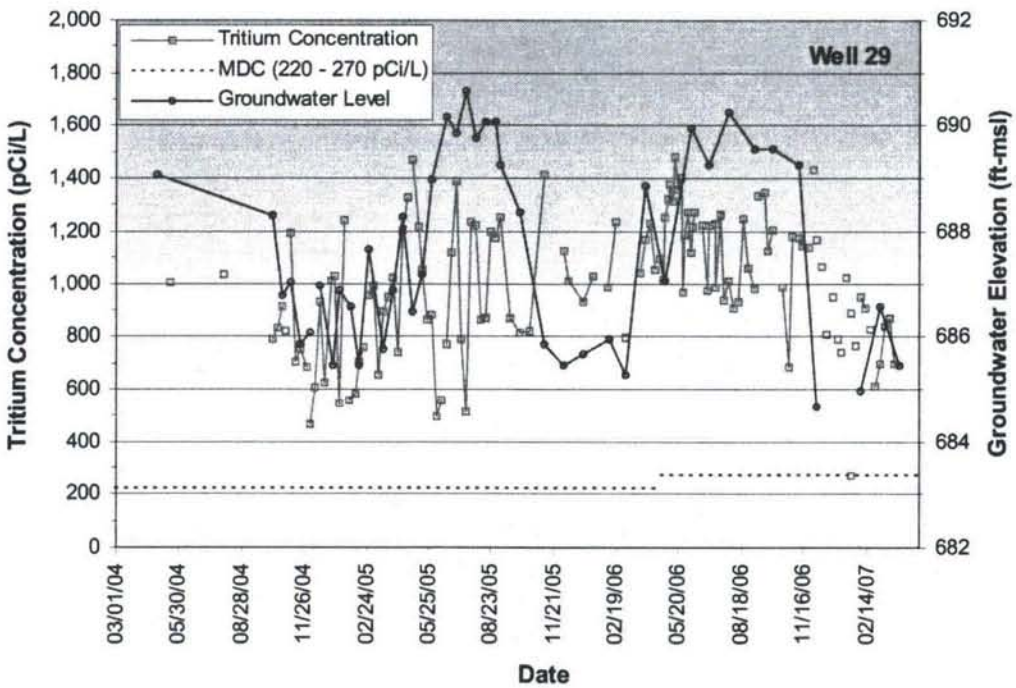


Figure 5.3 Time-Series Tritium Concentrations and Groundwater Levels at Wells 27 and 29

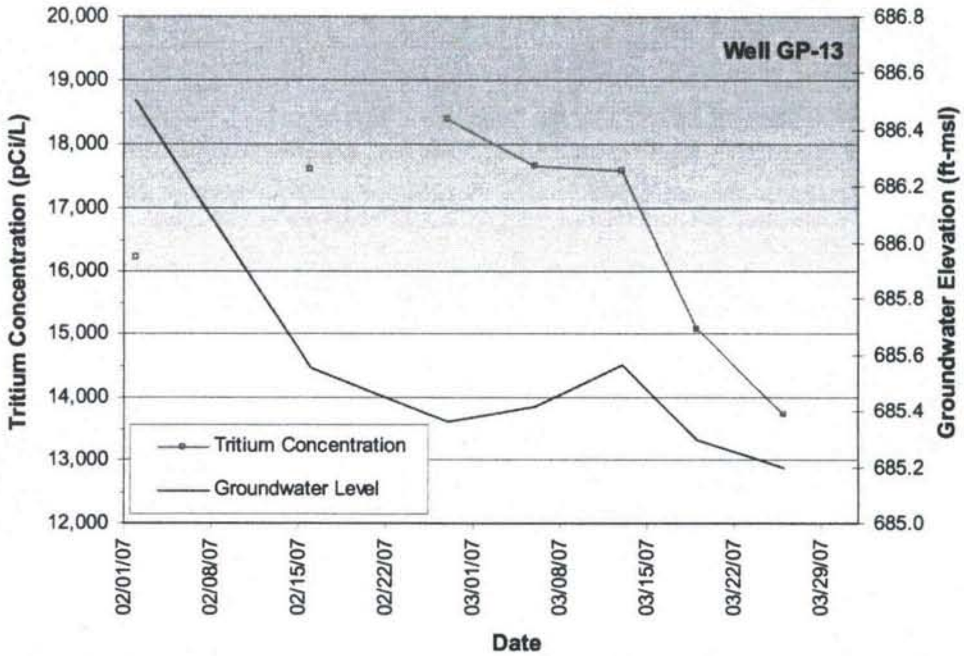


Figure 5.4 Time-Series Tritium Concentrations and Groundwater Levels at Well GP-13

Figure 5.5 shows the distribution of tritium based on shallow (soil) groundwater sampling during January and February 2007. In general, the highest tritium concentrations in the shallow groundwater system are associated with two distinct areas north and south of Units 1 and 2. Although data is sparse for the deeper flow regime (i.e., weathered bedrock and shallow bedrock), the extent of the tritium plume is reasonably bounded by sampling locations in the horizontal.

5.2 Tritium Sources

Current results suggest that sources of tritiated groundwater are primarily associated with past inadvertent releases of liquids containing radioisotopes. Relatively high groundwater tritium concentrations have been observed at wells 31 and GP-13, noting that there have been no observations exceeding the EPA Drinking Water Standard of 20,000 pCi/L for tritium (40 CFR 141.25).

Historically, remediation procedures for inadvertent liquid releases have chiefly involved the collection and screening of soil samples and limited water samples for radionuclides. However, the radionuclide analytes exclude short-lived isotopes such as tritium (see Section 2.3). Likewise, groundwater sampling associated with inadvertent liquid releases was not conducted during remediation. There is therefore a strong likelihood that tritium contamination from inadvertent liquid releases was not revealed due to the limitations of sampling and analytical protocols.

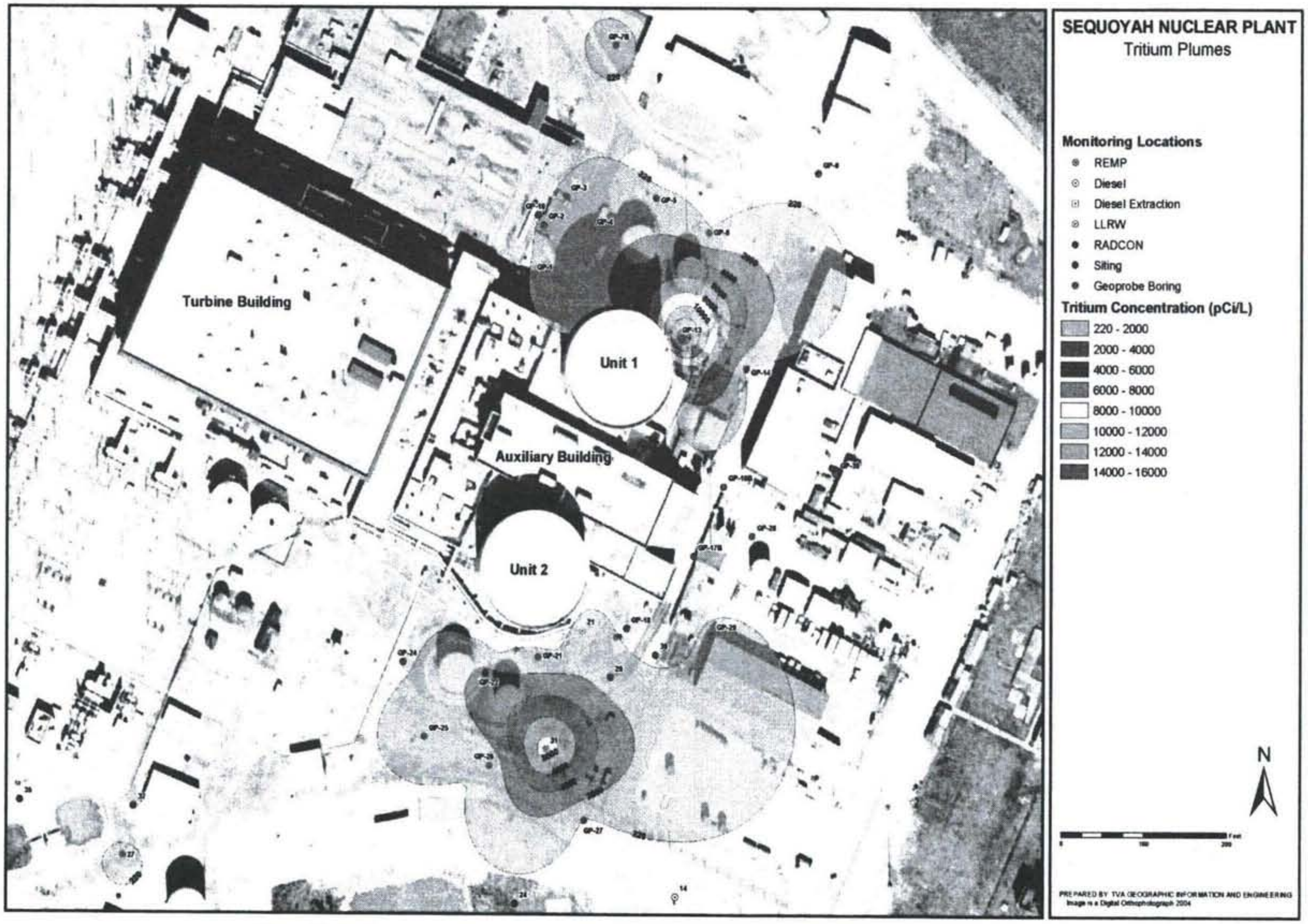


Figure 5.5 Spatial Distribution of Tritium from Groundwater Sampling During January and February 2007

An analog groundwater investigation of tritium releases at WBN suggests that leaks through the fuel transfer tube and seismic gap (between Unit 2 Reactor and Auxiliary Buildings) contaminated groundwater at the WBN site. Tritium concentrations in these source areas are nearly 100 million pCi/L and the release of only a small volume of water is necessary to produce elevated tritium concentrations in site groundwater. Inspections of SQN Unit 1 and 2 fuel transfer tubes, spent fuel pool, and associated components are currently being performed by SQN staff. These investigations are continuing and results are forthcoming.

Controlled airborne releases from the plant ventilation system may result in measurable atmospheric deposition of plant-related radionuclides (including tritium) in the vicinity of the site. Since this potential tritium source is not likely to be a major contributor to groundwater contamination, airborne release was not evaluated during this investigation.

Unit 1 – Elevated tritium concentrations in groundwater north of Unit 1 suggest that the inadvertent water release from the MFTDS in 1997 (see Section 2.3) is likely the primary source of shallow groundwater contamination in this vicinity. The estimated volume of water released by the MFTDS is 600 – 1,000 gallons. A secondary source of tritium contamination in this vicinity is related to relatively small volumes of water that drain from the RWST moat and have discharged to ground surface for >25 years. Observation of tritium in catch basin SS-6 near the Service Building is not completely explicable, but results suggest that the observed tritium concentration might be associated with direct discharges to the single line entering this catch basin.

Unit 2 – Tritium concentrations in groundwater south of Unit 2 suggest that inadvertent releases from the Unit 2 CDWE and additional Equipment Buildings (see Section 2.3) have contaminated shallow groundwater in this vicinity. A tertiary source of tritium contamination in this vicinity is related to the moat drain from the RWST that discharged to ground surface for >25 years. Tritium concentrations at well 27 appear to be of an isolated nature and may be related to leakage of the 12-inch waste condensate line.

5.3 Tritium Transport and Fate

Tritium is a conservative contaminant – it is not susceptible to attenuation via sorption or biochemical degradation. Reduction of tritium concentrations in the groundwater system at SQN will occur primarily by hydrodynamic dispersion and dilution. The dispersion process is related to variations in groundwater velocity that occur on a microscale by differences in media porosity and on a macroscale by variations in hydraulic conductivity. Dispersion will result in reductions of tritium concentrations with increasing distance from the source (e.g., the MFTDS railroad bay). Dispersion will be more pronounced in the soil horizon relative to the deeper and more transmissive weathered bedrock horizon. However, the fate and transport of tritium in the site groundwater system is also likely to be governed by avenues of relatively rapid groundwater movement that exist within bedding material of larger pipelines and tunnels, and possibly along the weathered bedrock horizon.

Groundwater and surface water level measurements during the study confirm that the Intake and Discharge Channel will ultimately be recipient to tritiated groundwater discharge from the site. Dilution ratios in the channels and subsequently the Tennessee River are dependent on plant operation and river flows.

5.4 Recommendations

No active remediation is recommended for the site due to the limited extent of tritium contamination, tritium concentrations in groundwater less than EPA Drinking Water Standard of 20,000 pCi/L (40 CFR 141.25), perceived low exposure and dose risks, and negligible potential for offsite groundwater migration. The following recommendations are submitted based on findings of this investigation.

Source Terms: Spatial data and anecdotal evidence suggest that tritium sources are primarily associated with past inadvertent releases of liquids containing radioisotopes. Additional groundwater sampling in the areas of GP-13 would assist in bounding the tritium plume on the north (Unit 1) side of the site. Sampling would involve the installation of 6 – 8 shallow soil borings to confirm the extent of tritium contamination.

There are no bedrock borings located in close proximity to Units 1 and 2 that can be used to examine the vertical distribution of tritium that might extend into the shallow Conasauga bedrock. Two bedrock borings extending into the upper 20 ft of bedrock are recommended for the zones exhibiting relatively high tritium concentrations (north and south of Units 1 and 2). Results should be examined collectively to verify that higher tritium concentrations do not exist at excessive concentrations within the shallow bedrock flow system.

It is likely that tritium contamination from inadvertent liquid releases was not revealed in past investigations due to the limitations of sampling and analytical protocols. SQN procedures directed towards investigation and remediation of future releases should be developed or modified to identify short-lived isotopes such as tritium. Confirmatory sampling of environmental media following remediation of a spill should meet the MDCs of applicable regulatory criteria. In most cases, a professional engineer with expertise in hydrogeology should be consulted to assist in remediation investigations.

The components investigation currently being conducted by SQN staff should continue to substantiate that no releases to groundwater have occurred from internal sources. Should problems be identified, their remedies should extend to external environs as necessary.

Routine Onsite Groundwater Monitoring: Routine groundwater quality and water level monitoring should be continued at a quarterly frequency at wells 31, GP-13, and W21 for a minimum of two years. These data should be reviewed on an annual basis by a professional engineer with expertise in hydrogeology and groundwater science. In addition to tritium, boron should be considered as an analyte since it is typically added to primary cooling water as a neutron moderator. Therefore, when detected at concentrations greater than background, boron can be an indicator of leaks from primary systems. Results of routine groundwater sampling should be reviewed annually by a professional engineer with expertise in hydrogeology.

Groundwater sampling protocols have been prepared by TVA and standard forms are available for use. In addition, the NRC (1979) and ASTM (2006) provide standard guidelines for groundwater sampling. The SQN staff should assure that acceptable groundwater sampling protocols are being utilized. In addition to groundwater collection methods, these practices also extend to: sample handling, labeling, storage, shipment and chain-of-custody procedures; qualification and training requirements for sampling personnel; applicable regulatory limits; analytical methods and MDCs, required analytical method uncertainties; quality control samples and acceptance criteria; required number of samples per analytical batch; and validation methods.

REMP Onsite Groundwater Monitoring: Bedrock well W5 is currently the only onsite well being used for REMP groundwater monitoring purposes. The well location and type is poorly suited for rapid detection of groundwater contamination from primary plant systems. Well W5 resides too far from the plant, is situated adjacent to the Intake Channel, and is developed in bedrock. Consideration should be given to an alternate well location(s) and type (e.g., well immediate to the site, along groundwater gradient, and appropriately screened).

Data Management and Quality: The current data management procedures result in significant difficulties related to groundwater data acquisition and authentication. TVA and SQN should consider a programmatic evaluation of data management and quality practices to ensure that analytical results are documented, retained, and readily retrievable. At a minimum, documented analytical data shall contain the following information:

- Sample identification (e.g., location and well identification);
- Sample date and time;
- Measured concentration for all radionuclides where results have been reported (whether or not above the detection criteria, or positive or negative);
- Measurement uncertainty;
- Achieved MDCs;
- Records of data validation and verification;
- Identification of missing sample results;

- Analytical method(s).

Development of a database should be considered that meets criteria described in American Nuclear Insurers Information Bulletin 80-1A. The database developed by TVA for the fossil fuel groundwater monitoring program would serve as an ideal platform for groundwater data management.

Well Protection and Abandonment: Analytical results from repeated sampling at several site wells indicate that they can be abandoned. Wells that are deemed of no strategic importance have not exhibited tritium concentrations >MDCs and are in close proximity to other monitoring wells. Wells recommended for abandonment include: 30, 32, 34, 35, UN1W, UNW2, and UNW3.

Wells installed for monitoring along the waste condensate lines and during this study do not possess well head protection. Lockable well head protective covers, balusters, and/or flush-mount covers should be installed at these wells. Data suggest that wells 14 and W21 well head seals have been damaged, allowing direct entry of rainfall runoff. These well heads should be repaired.

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APPENDIX A

WELL CONSTRUCTION LOGS

ROCK MONITORING WELL INSTALLATION RECORD

PROJECT SEQUOYAH NUCLEAR PLANT

WELL NUMBER W1 | INSTALLATION DATE

PLANT COORDINATES EAST -1272.6 ft | NORTH 800.1 ft

GROUND SURFACE ELEVATION 705.6 ftmsl | TOP OF INNER CASING 708.87 ftmsl

BACKFILL MATERIAL SAND & PEA GRAVEL | CASING DIAMETER 6"

CASING MATERIAL SOLID STEEL CASING | DRILLING TECHNIQUE IN ROCK PERCUSSION

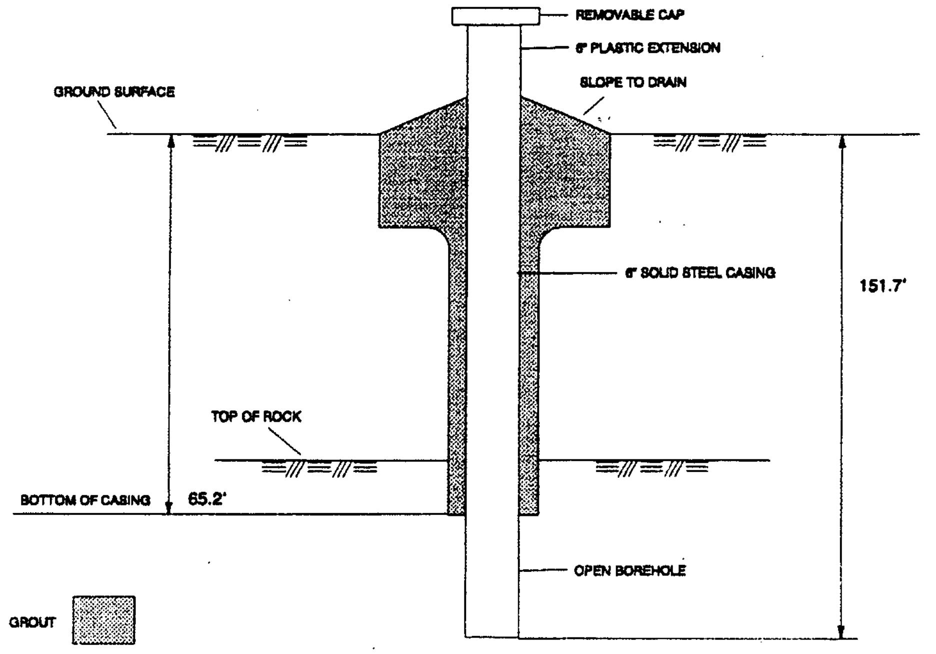
DRILLING TECHNIQUE IN SOIL AUGER | DRILLING CONTRACTOR

OUTER BOREHOLE DIAMETER | OPEN BOREHOLE DIAMETER 6"

LOCKABLE COVER ? NO

COMMENTS PLASTIC PIPE ADDED TO RAISE THIS WELL 4.37 ft.

(NOT TO SCALE)



ENG LAB 7/25/91

MONITORING WELL INSTALLATION RECORD

PROJECT: SEQUOYAH NUCLEAR PLANT

WELL NUMBER: W2
INSTALLATION DATE:

PLANT COORDINATES EAST: -1105.5 ft
NORTH: -1271.6 ft

GROUND SURFACE ELEVATION: 700.1 ftmsl
TOP OF INNER CASING: 700.91 ftmsl

BACKFILL MATERIAL: SAND & PEA GRAVEL
CASING DIAMETER: 6"

CASING MATERIAL: SOLID STEEL CASING
DRILLING TECHNIQUE IN ROCK: PERCUSSION

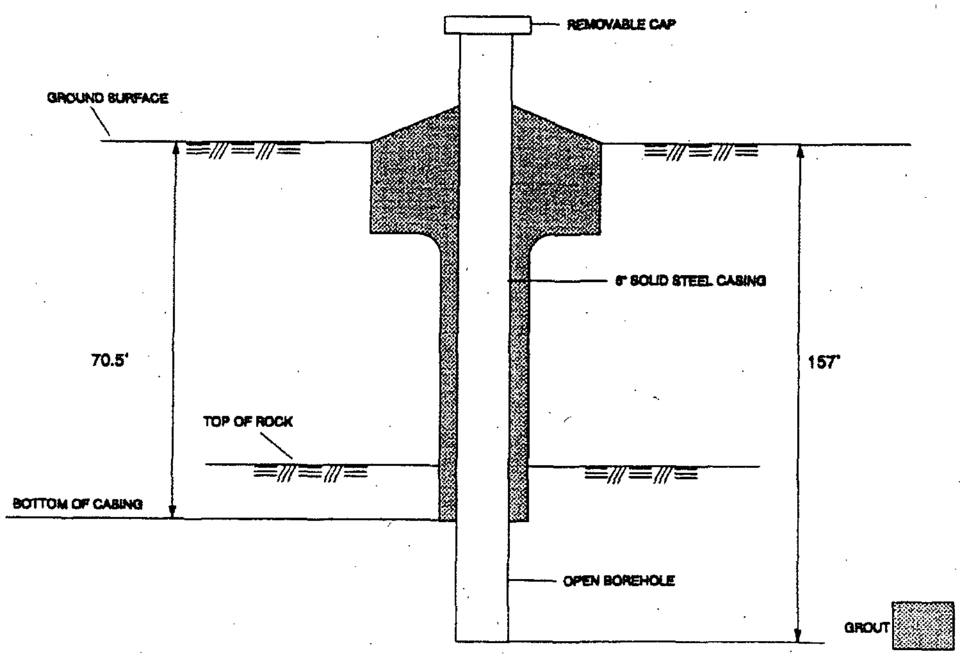
DRILLING TECHNIQUE IN SOIL: AUGER
DRILLING CONTRACTOR:

OUTER BOREHOLE DIAMETER:
OPEN BOREHOLE DIAMETER: 6"

LOCKABLE COVER ?: NO

COMMENTS: NEAR GAS/DIESEL TANKS

(NOT TO SCALE)



ENG LAB 7/25/91

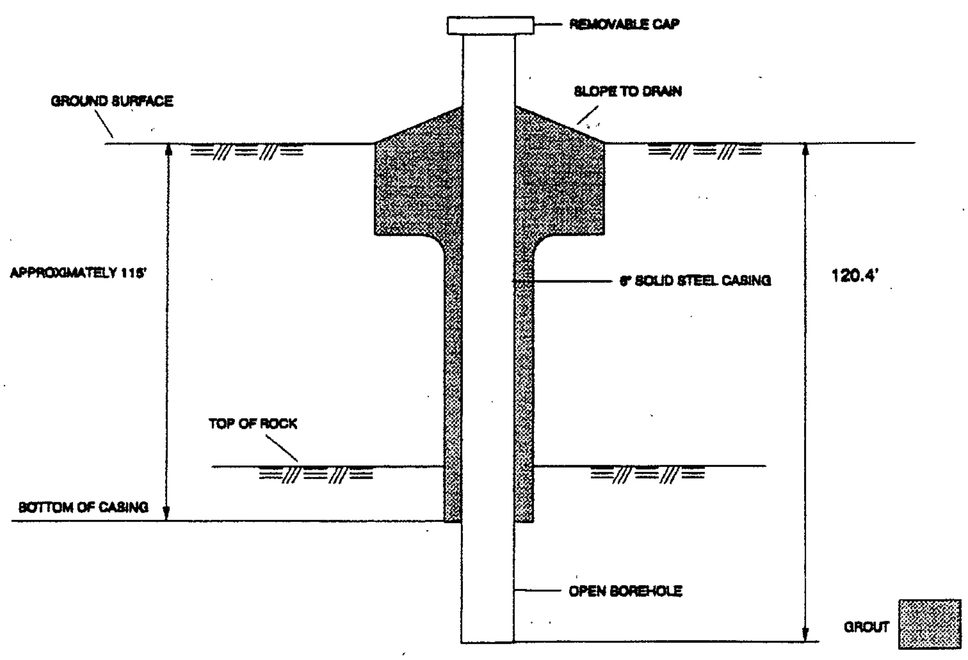
MONITORING WELL INSTALLATION RECORD

PROJECT: SEQUOYAH NUCLEAR PLANT

WELL NUMBER	W4	INSTALLATION DATE	
PLANT COORDINATES EAST	948.1 ft	NORTH	39.6 ft
GROUND SURFACE ELEVATION	732.3 ftmsl	TOP OF INNER CASING	742.27 ftmsl
BACKFILL MATERIAL	SAND & PEA GRAVEL	CASING DIAMETER	6"
CASING MATERIAL	SOLID STEEL CASING	DRILLING TECHNIQUE IN ROCK	PERCUSSION
DRILLING TECHNIQUE IN SOIL	AUGER	DRILLING CONTRACTOR	
OUTER BOREHOLE DIAMETER		OPEN BOREHOLE DIAMETER	
LOCKABLE COVER ?			

COMMENTS

(NOT TO SCALE)



ENG LAB 7/25/91

MONITORING WELL INSTALLATION RECORD

PROJECT: SEQUOYAH NUCLEAR PLANT

WELL NUMBER: W5

INSTALLATION DATE:

PLANT COORDINATES EAST: 146.0 ft

NORTH: 761.0 ft

GROUND SURFACE ELEVATION: 696.1 ftmsl

TOP OF INNER CASING: 697.14 ftmsl

BACKFILL MATERIAL: SAND & PEA GRAVEL

CASING DIAMETER: 6"

CASING MATERIAL: SOLID STEEL CASING

DRILLING TECHNIQUE IN ROCK: PERCUSSION

DRILLING TECHNIQUE IN SOIL: AUGER

DRILLING CONTRACTOR:

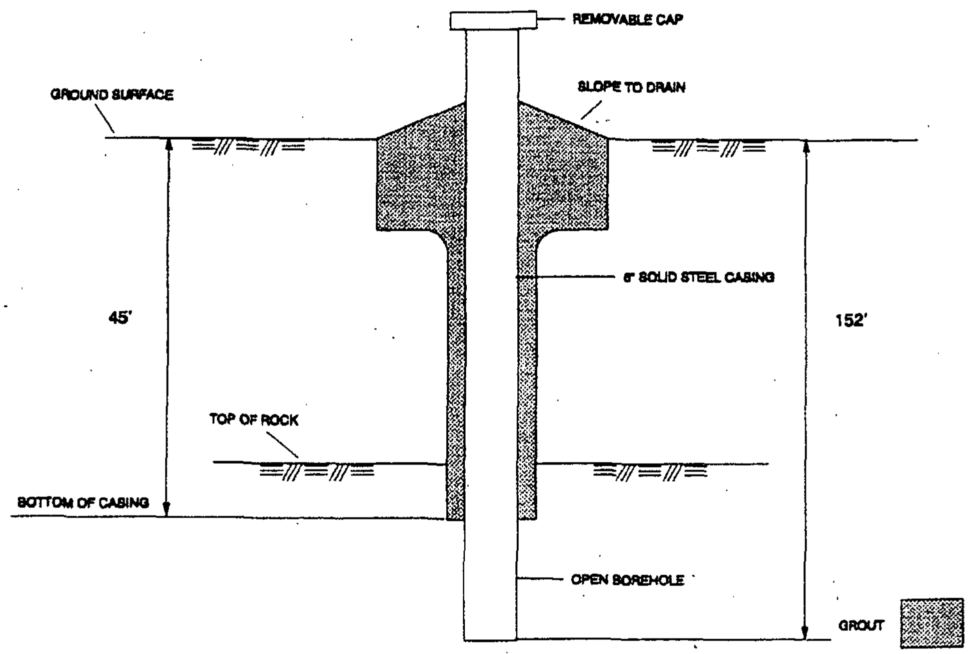
OUTER BOREHOLE DIAMETER:

OPEN BOREHOLE DIAMETER: 6"

LOCKABLE COVER ?:

COMMENTS:

(NOT TO SCALE)



ENG LAB 7/25/91

MONITORING WELL INSTALLATION RECORD

PROJECT SEQUOYAH NUCLEAR PLANT

WELL NUMBER L6

INSTALLATION DATE 8-11-81

PLANT COORDINATES EAST 1885.7 ft

NORTH -336.4 ft

GROUND SURFACE ELEVATION 733.8 ft-MSL

TOP OF INNER CASING 734.8 ft-MSL

BACKFILL MATERIAL SAND & PEA GRAVEL

CASING DIAMETER 3"

CASING MATERIAL PVC

DRILLING TECHNIQUE IN ROCK PERCUSSION

DRILLING TECHNIQUE IN SOIL AUGER

DRILLING CONTRACTOR

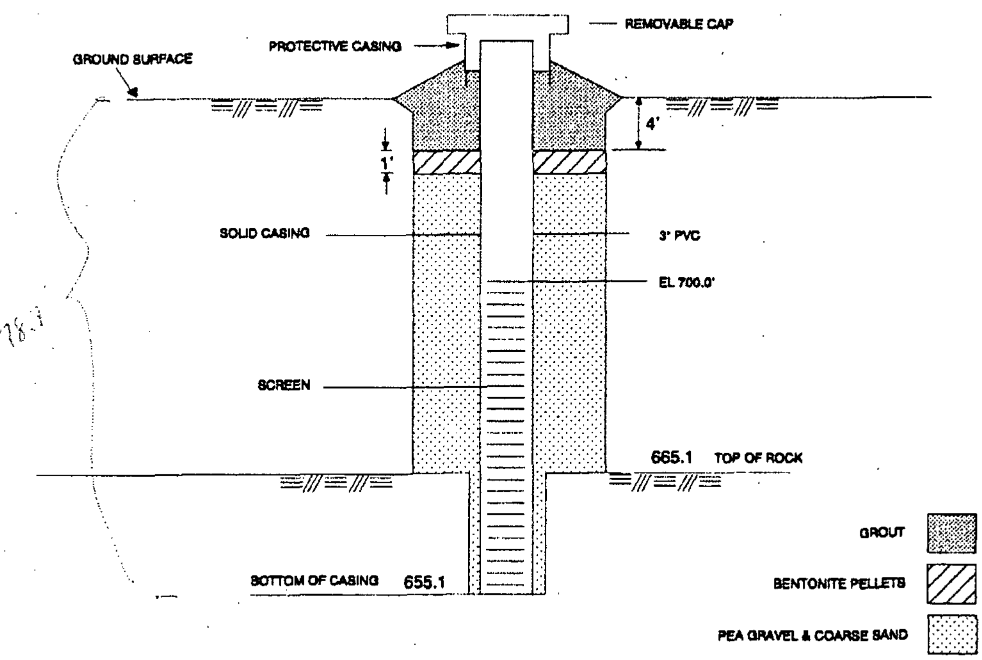
OUTER BOREHOLE DIAMETER 12"

OPEN BOREHOLE DIAMETER 5"

LOCKABLE COVER ? NO LOCK

COMMENTS .010" SLOT WRAPPED WITH FIBER GLASS CLOTH

(NOT TO SCALE)



ENG LAB 7/25/91

MONITORING WELL INSTALLATION RECORD

PROJECT: SEQUOYAH NUCLEAR PLANT

WELL NUMBER: L7
INSTALLATION DATE: 8-11-81

PLANT COORDINATES EAST: 1390.6 ft
NORTH: -8.0 ft

GROUND SURFACE ELEVATION: 731.0 ft-MSL
TOP OF INNER CASING: 733.1 ft-MSL

BACKFILL MATERIAL: SAND & PEA GRAVEL
CASING DIAMETER: 3"

CASING MATERIAL: PVC
DRILLING TECHNIQUE IN ROCK: PERCUSSION

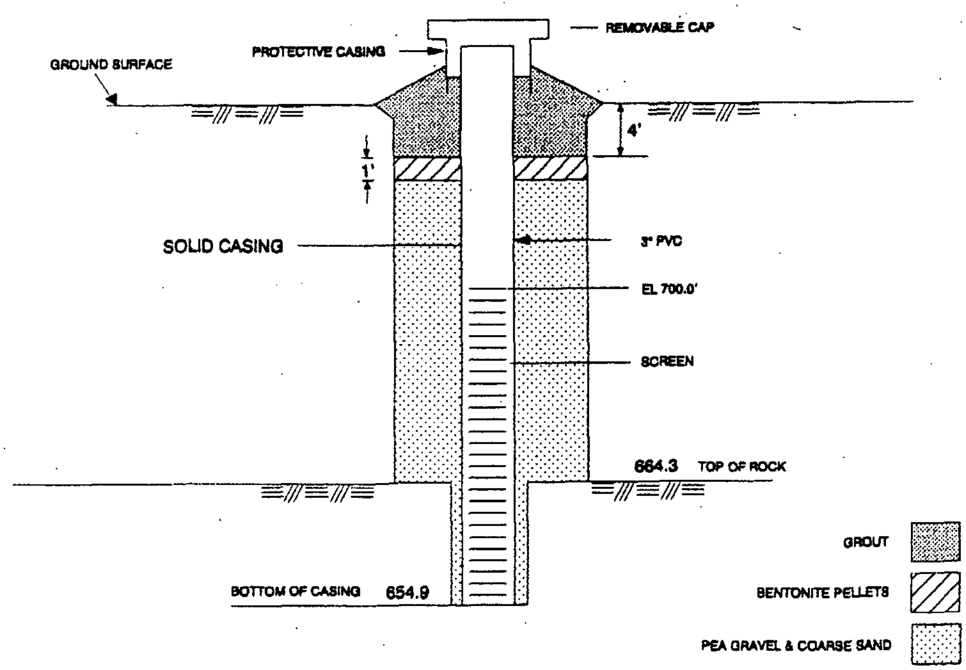
DRILLING TECHNIQUE IN SOIL: AUGER
DRILLING CONTRACTOR:

OUTER BOREHOLE DIAMETER: 12"
OPEN BOREHOLE DIAMETER: 5"

LOCKABLE COVER ?: NO LOCK

COMMENTS: .010" SLOT WRAPPED WITH FIBER GLASS CLOTH

(NOT TO SCALE)



ENG LAB 7/25/91

DESTROYED

MONITORING WELL INSTALLATION RECORD

PROJECT SEQUOYAH NUCLEAR PLANT

WELL NUMBER W8

INSTALLATION DATE

PLANT COORDINATES EAST 400.0 ft

NORTH 680.0 ft

GROUND SURFACE ELEVATION APPROX. 692.0 ft-MSL

TOP OF INNER CASING 694.1 ft-MSL

BACKFILL MATERIAL SAND & PEA GRAVEL

CASING DIAMETER 6"

CASING MATERIAL SOLID STEEL CASING

DRILLING TECHNIQUE IN ROCK PERCUSSION

DRILLING TECHNIQUE IN SOIL AUGER

DRILLING CONTRACTOR

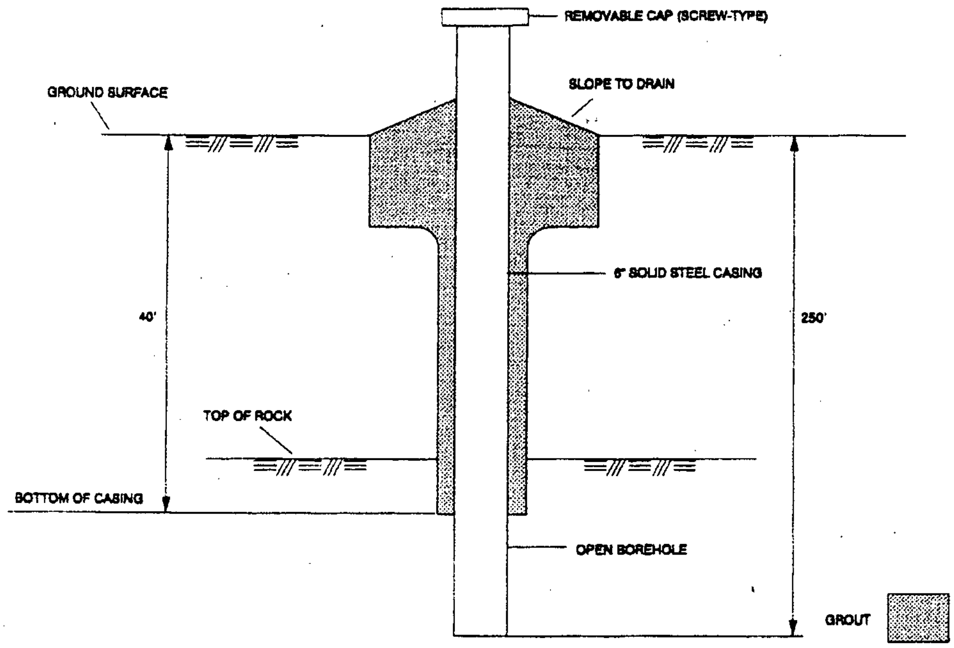
OUTER BOREHOLE DIAMETER

OPEN BOREHOLE DIAMETER 6"

LOCKABLE COVER ?

COMMENTS AUTOMATIC SAMPLER (NOT OPERATIONAL) AT THIS LOCATION.

(NOT TO SCALE)

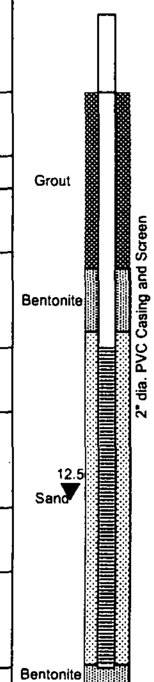


ENG LAB 7/25/91

TVA **Sequoyah Nuclear Plant** **Boring ID: W14**

Depth (ft)	Elevation (ft)	Lithology	Description
0	705		GRAVEL, (FILL)
			Not Sampled
			GRAVEL, roots (FILL)
5	700		Not Sampled
			Crumbly, brown, sandy, SILTY CLAY, diesel odor (FILL?)
10	695		Not Sampled
			Crumbly, dark brown, SANDY CLAY, layer of greenish clay, diesel odor (FILL?)
15	690		Not Sampled
			Crumbly, dark brown, sandy, SILTY CLAY, roots/twigs, diesel odor (FILL?)
20	685		Not Sampled
			Crumbly, dark brown, sandy, SILTY CLAY, roots/twigs, diesel odor (FILL?)
25	680		Boring Terminated at 25.6 ft BGS

Piezometer Construction Diagram



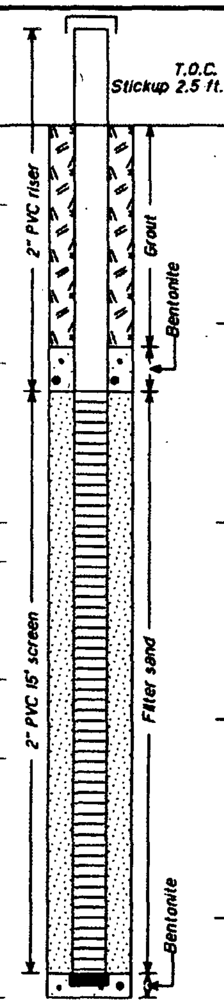
Project Name: Sequoyah Nuclear Plant	Drilling Date: 11/23/1992	Easting: 2271537
Company Name: TVA	Drilling Company: MACTEC	Northing: 304487
Location: South of Unit #2 Reactor Bldg	Drilling Method: Hollow Stem Auger	Top of Casing (ft): 707.88
	Well Depth (ft): 18.75	Top of Ground (ft): 705.2

Tennessee Valley Authority

LOG OF BORING 22

WELL CONSTRUCTION DETAIL

BLOWS/FT	FID (ppm)	ELEV. (ft-msl)	DEPTH (ft)	MATERIALS DESCRIPTION
				Light brown gravelly clay fill
				Yellow-orange silty clay with roots
	16			
	55		5	
				Yellow-orange silty clay with light gray silt motteling and root in silt stringers
	40			
	62			
	18		10	Dark gray weathered silty shale
	12			Dark gray to yellow-orange weathered fissile shale with dark brown clay stringers
	1			
	0			Greenish gray to dark brown weathered fissile and silty shale
			15	
	0			Olive gray to dark brown weathered silty shale;
	0			
			20	
				boring terminated
			25	

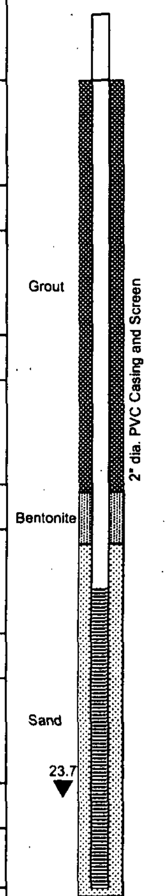


PROJECT Sequoyah Nuclear Plant
DRILLING COMPANY Tri-State
LOCATION Soddy Daisy, Tn
DATE DRILLED
DRILL RIG Hollow Stem Auger
SURFACE ELEVATION 698.4 feet-msl
LOGGER/ENGINEER Hank Julian
T.O.C. ELEVATION 700.88 feet-msl
WATER LEVEL (INITIAL)
WATER LEVEL (24-HOUR)

TVA	Sequoyah Nuclear Plant	Boring ID:	W21

Depth (ft)	Elevation (ft)	Lithology	Description
0	705		
5	700		GRAVEL, with dark red-brown silty clay, (FILL)
			Not Sampled
10	695		Dark red-brown, SILTY CLAY, with rock fragments (FILL)
			Not Sampled
15	690		Tan-brown and greenish gray weathered SILTY SHALE (FILL)
			Not Sampled
20	685		Light tan-brown and red SILTY SHALE (FILL)
			Not Sampled
25	680		Red-brown, SILTY SHALE (FILL)
			Not Sampled
			Boring Terminated at 27.3 ft BGS

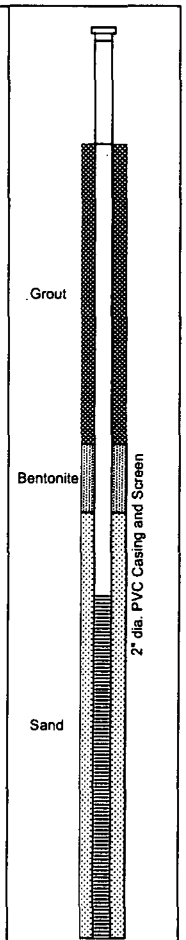
Piezometer Construction Diagram



Project Name: Sequoyah Nuclear Plant	Drilling Date: 1/20/1993	Easting: 2271423.4
Company Name: TVA	Drilling Company: MACTEC	Northing: 304779.2
Location: South of Unit #2 Reactor Bldg	Drilling Method: Hollow Stem Auger	Top of Casing (ft): 706.23
	Well Depth (ft): 27.3	Top of Ground (ft): 704.4

TVA | **Sequoyah Nuclear Plant** | **Boring ID: 24**

Depth (ft)	Elevation (ft)	Lithology	Description	Piezometer Construction Diagram
0	705			
5	700			
10	695			
15	690			
20	685			

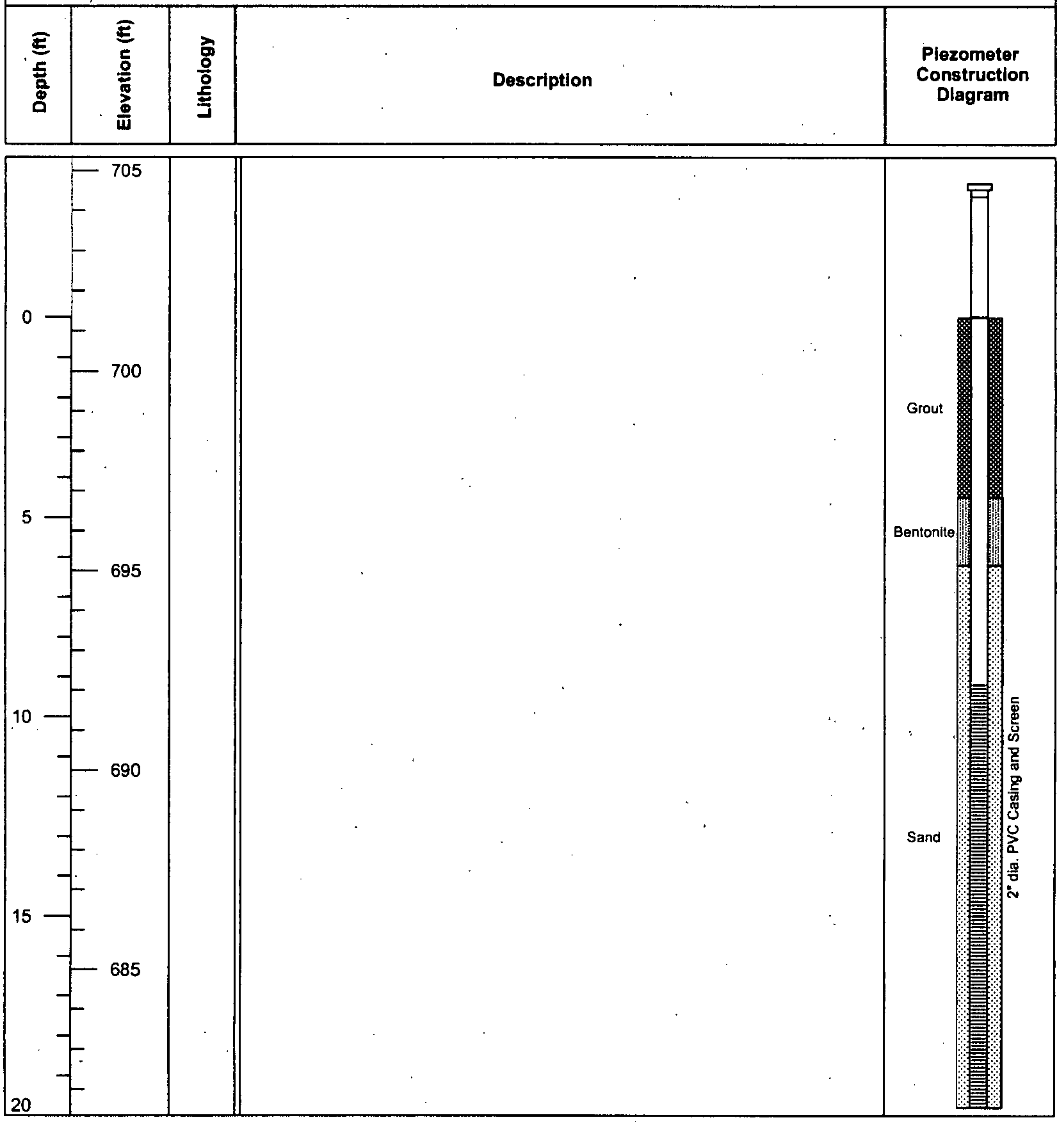


Project Name: Sequoyah Nuclear Plant
Company Name: TVA
Location: East of Discharge Channel

Drilling Date: 2/20/2002
Drilling Company: TVA
Drilling Method: 8" H.S.A.
Well Depth (ft): 23.2

Easting: 2271341.71
Northing: 304478.66
Top of Casing (ft): 705.7
Top of Ground (ft): 705.65

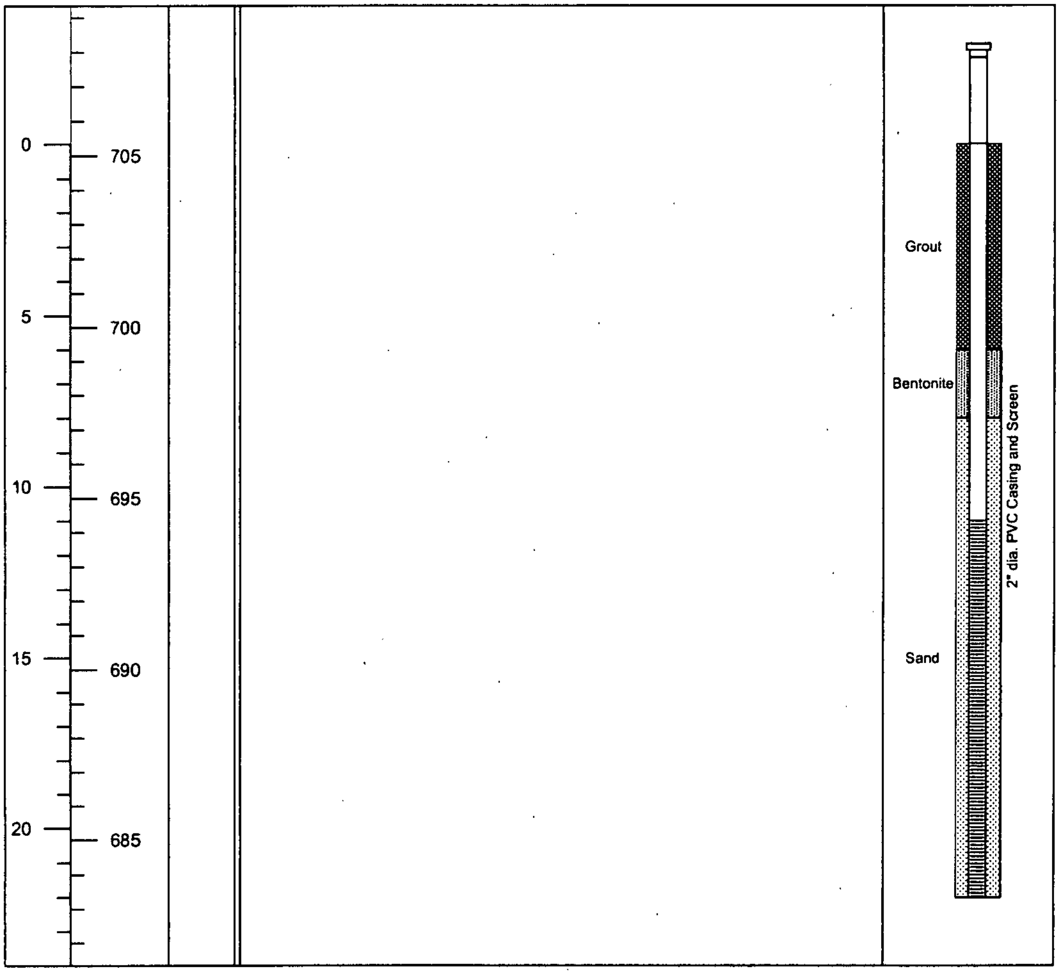
Sequoyah Nuclear Plant **Boring ID: 25**



Project Name: Sequoyah Nuclear Plant	Drilling Date: 2/20/2002	Easting: 2271599.77
Company Name: TVA	Drilling Company: TVA	Northing: 304238.91
Location: East of Discharge Channel	Drilling Method: 8" H.S.A.	Top of Casing (ft): 704.37
	Well Depth (ft): 19.8	Top of Ground (ft): 701.34

TVA	Sequoyah Nuclear Plant	Boring ID: 27

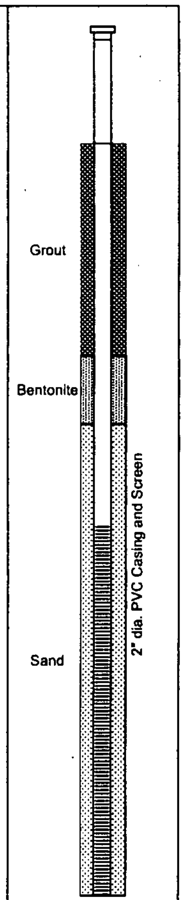
Depth (ft)	Elevation (ft)	Lithology	Description	Piezometer Construction Diagram



Project Name: Sequoyah Nuclear Plant	Drilling Date: 2/21/2002	Easting: 2270865.63
Company Name: TVA	Drilling Company: TVA	Northing: 304530.46
Location: South of Unit #2 Reactor Bldg	Drilling Method: 8" H.S.A.	Top of Casing (ft): 705.46
	Well Depth (ft): 22	Top of Ground (ft): 705.34

TVA **Sequoyah Nuclear Plant** **Boring ID: 28**

Depth (ft)	Elevation (ft)	Lithology	Description	Piezometer Construction Diagram
	705			
0				
	700			
5				
	695			
10				
	690			
15				
	685			
20				

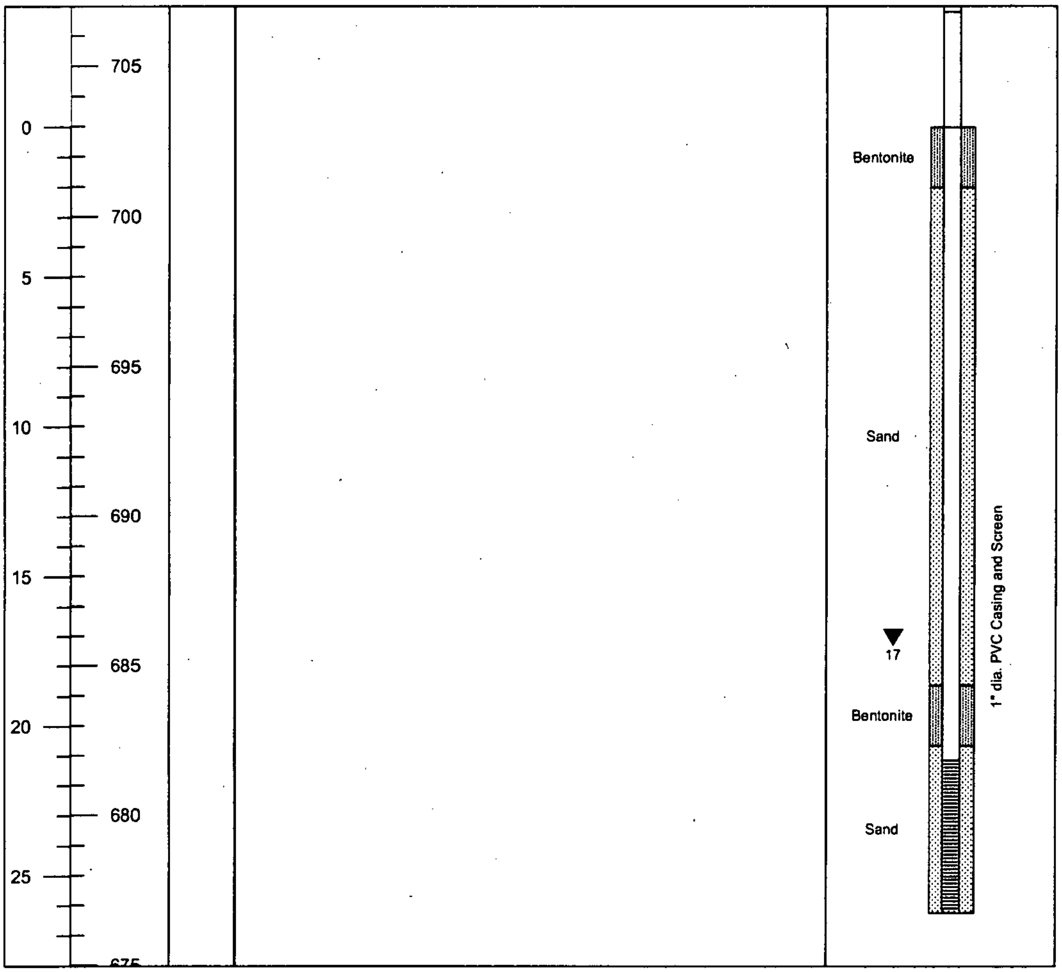


Project Name: Sequoyah Nuclear Plant	Drilling Date: 2/21/2002	Easting: 2270758.84
Company Name: TVA	Drilling Company: TVA	Northing: 304204.56
Location: South of Unit #2 Reactor Bldg	Drilling Method: 6" Air Rotary	Top of Casing (ft): 704.44
	Well Depth (ft): 22	Top of Ground (ft): 704.6

TVA

Sequoyah Nuclear Plant — Boring ID: 29

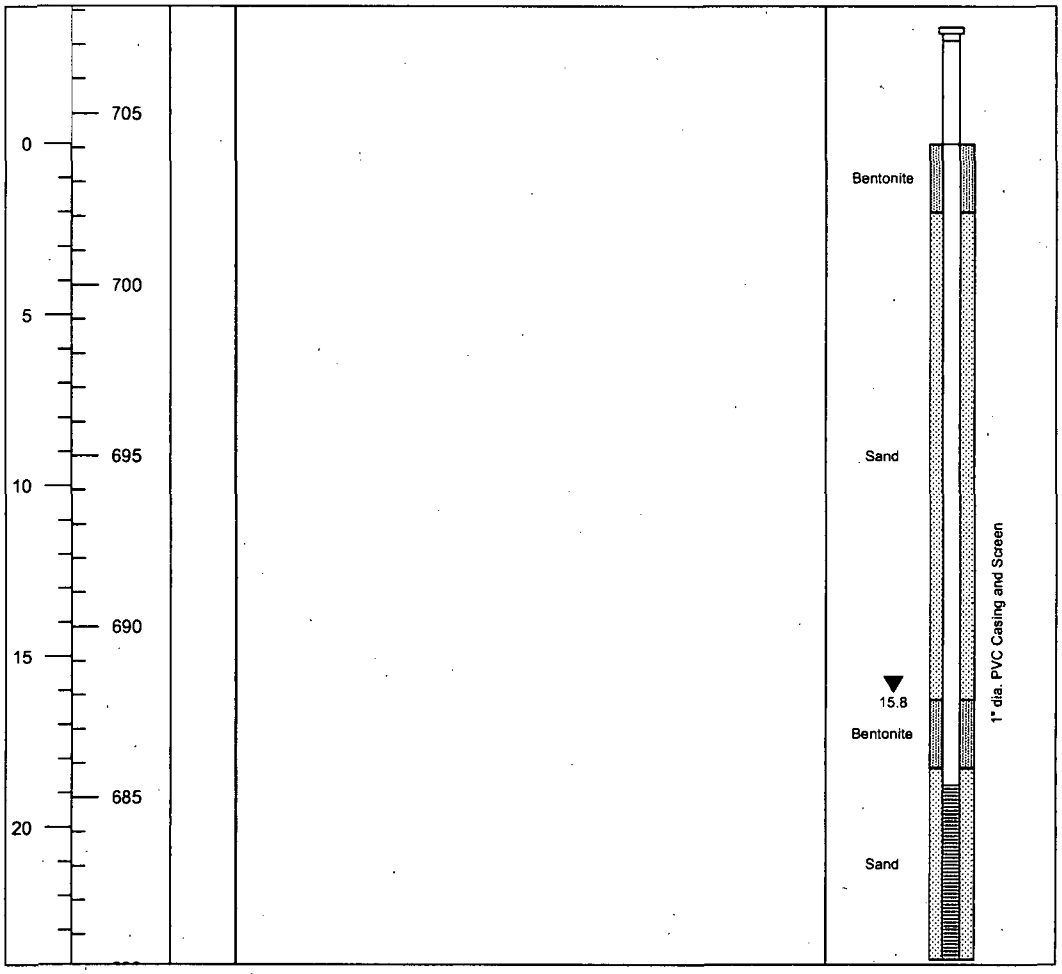
Depth (ft)	Elevation (ft)	Lithology	Description	Piezometer Construction Diagram



Project Name: Sequoyah Nuclear Plant	Drilling Date: 04/27/2004	Easting: 2271457.69
Company Name: TVA	Drilling Company: TVA	Northing: 304728.27
Location: South of Unit #2 Reactor Bldg	Drilling Method: Geoprobe	Top of Casing (ft): 706.06
	Well Depth (ft): 26.12	Top of Ground (ft): 702.97

TVA	Sequoyah Nuclear Plant	Boring ID: 30

Depth (ft)	Elevation (ft)	Lithology	Description	Piezometer Construction Diagram



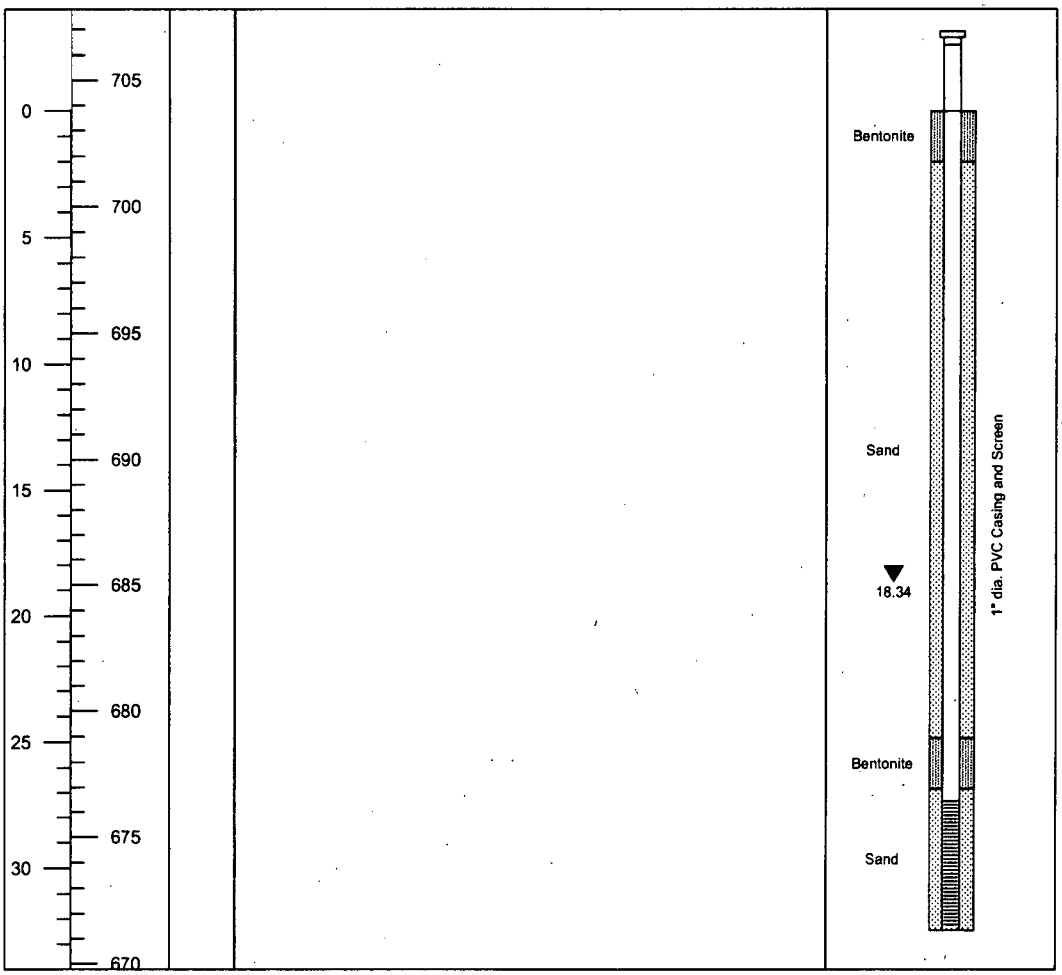
Project Name: Sequoyah Nuclear Plant	Drilling Date: 04/27/2004	Easting: 2271512.24
Company Name: TVA	Drilling Company: TVA	Northing: 304752.93
Location: South of Unit #2 Reactor Bldg	Drilling Method: Geoprobe	Top of Casing (ft): 707.15
	Well Depth (ft): 23.75	Top of Ground (ft): 704.13

TVA

Sequoyah Nuclear Plant

Boring ID: 31

Depth (ft)	Elevation (ft)	Lithology	Description	Piezometer Construction Diagram



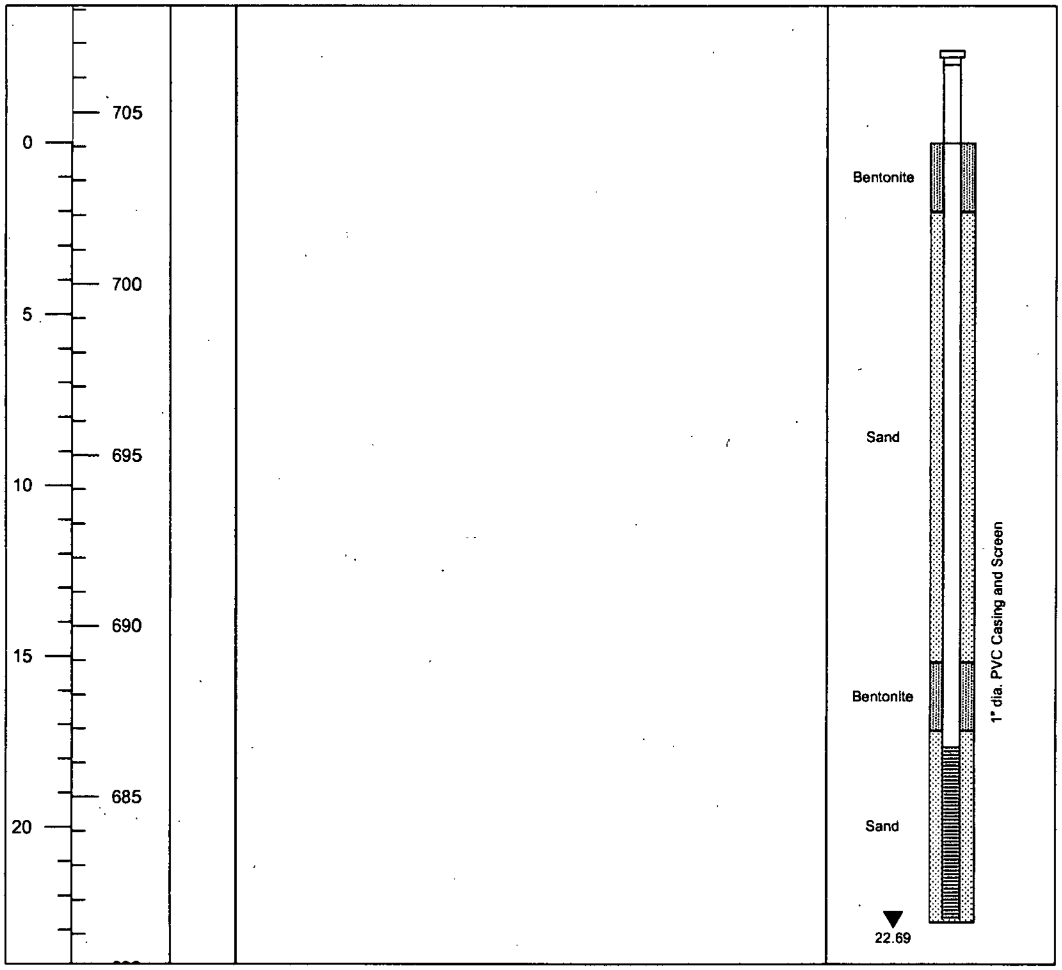
Project Name: Sequoyah Nuclear Plant	Drilling Date: 04/27/2004	Easting: 2271378.74
Company Name: TVA	Drilling Company: TVA	Northing: 304648.84
Location: South of Unit #2 Reactor Bldg	Drilling Method: Geoprobe	Top of Casing (ft): 706.54
	Well Depth (ft): 32.33	Top of Ground (ft): 703.78

TVA

Sequoyah Nuclear Plant

Boring ID: 32

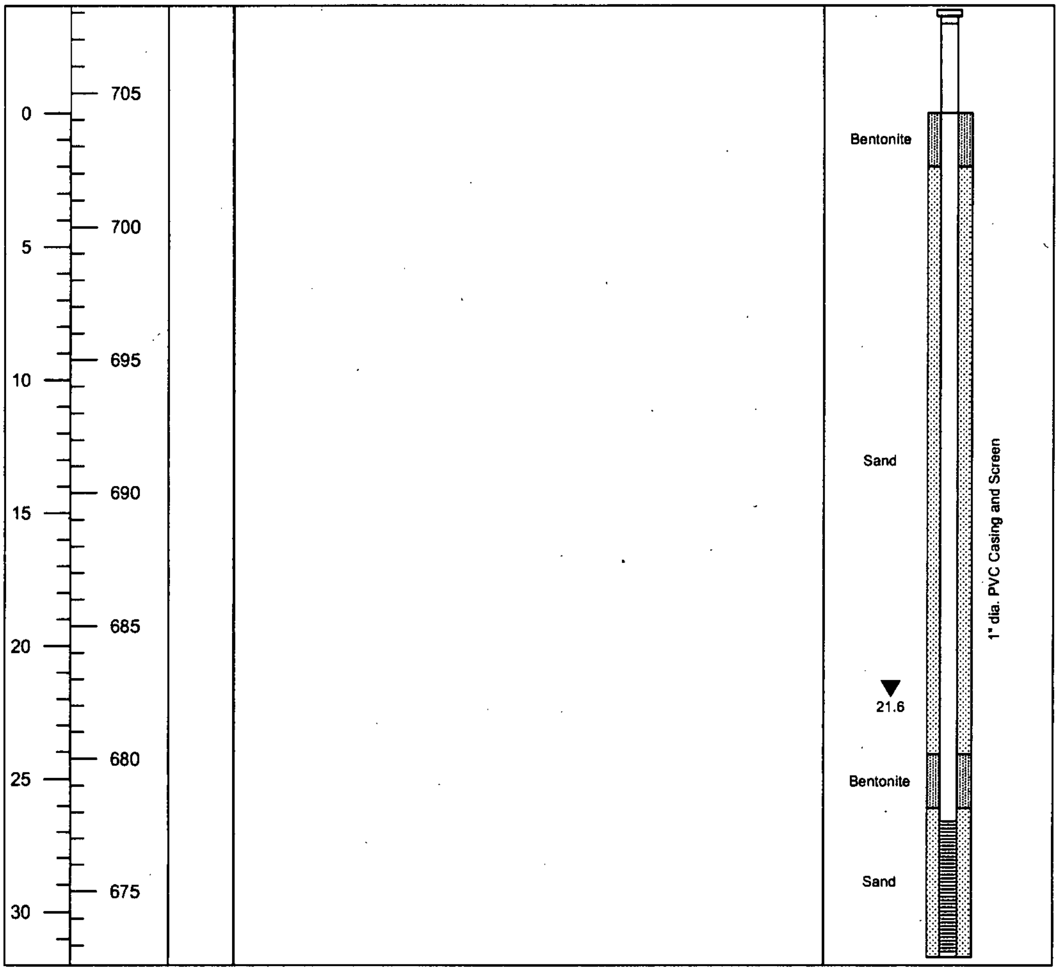
Depth (ft)	Elevation (ft)	Lithology	Description	Piezometer Construction Diagram



Project Name: Sequoyah Nuclear Plant	Drilling Date: 04/28/2004	Easting: 2270878.28
Company Name: TVA	Drilling Company: TVA	Northing: 304584.83
Location: South of Unit #2 Reactor Bldg	Drilling Method: Geoprobe	Top of Casing (ft): 706.33
	Well Depth (ft) : 22.66	Top of Ground (ft): 704.12

Sequoyah Nuclear Plant **Boring ID: 33**
DESTROYED

Depth (ft)	Elevation (ft)	Lithology	Description	Piezometer Construction Diagram



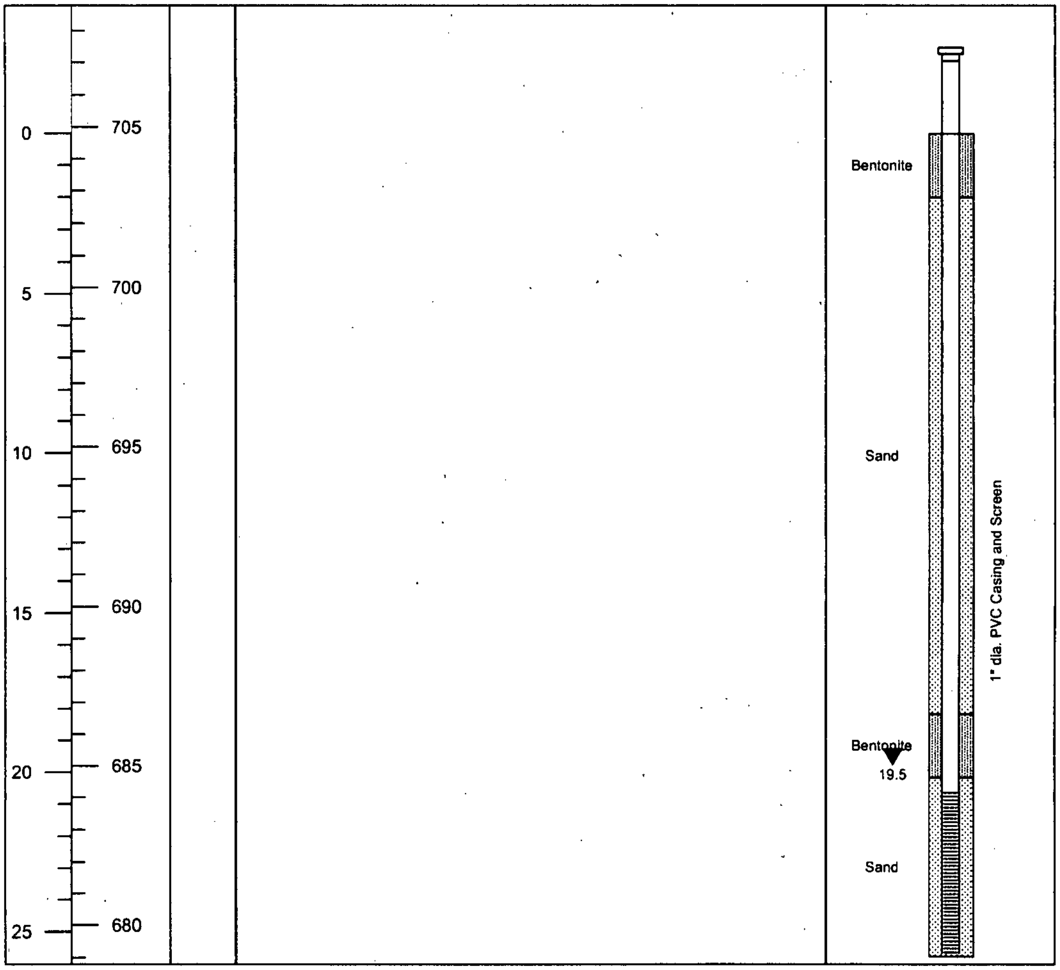
Project Name: Sequoyah Nuclear Plant	Drilling Date: 04/28/2004	Easting: 2270925.57
Company Name: TVA	Drilling Company: TVA	Northing: 304501.21
Location: South of Unit #2 Reactor Bldg	Drilling Method: Geoprobe	Top of Casing (ft): 708.69
	Well Depth (ft) : 31.58	Top of Ground (ft): 704.25

TVA

Sequoyah Nuclear Plant

Boring ID: 34

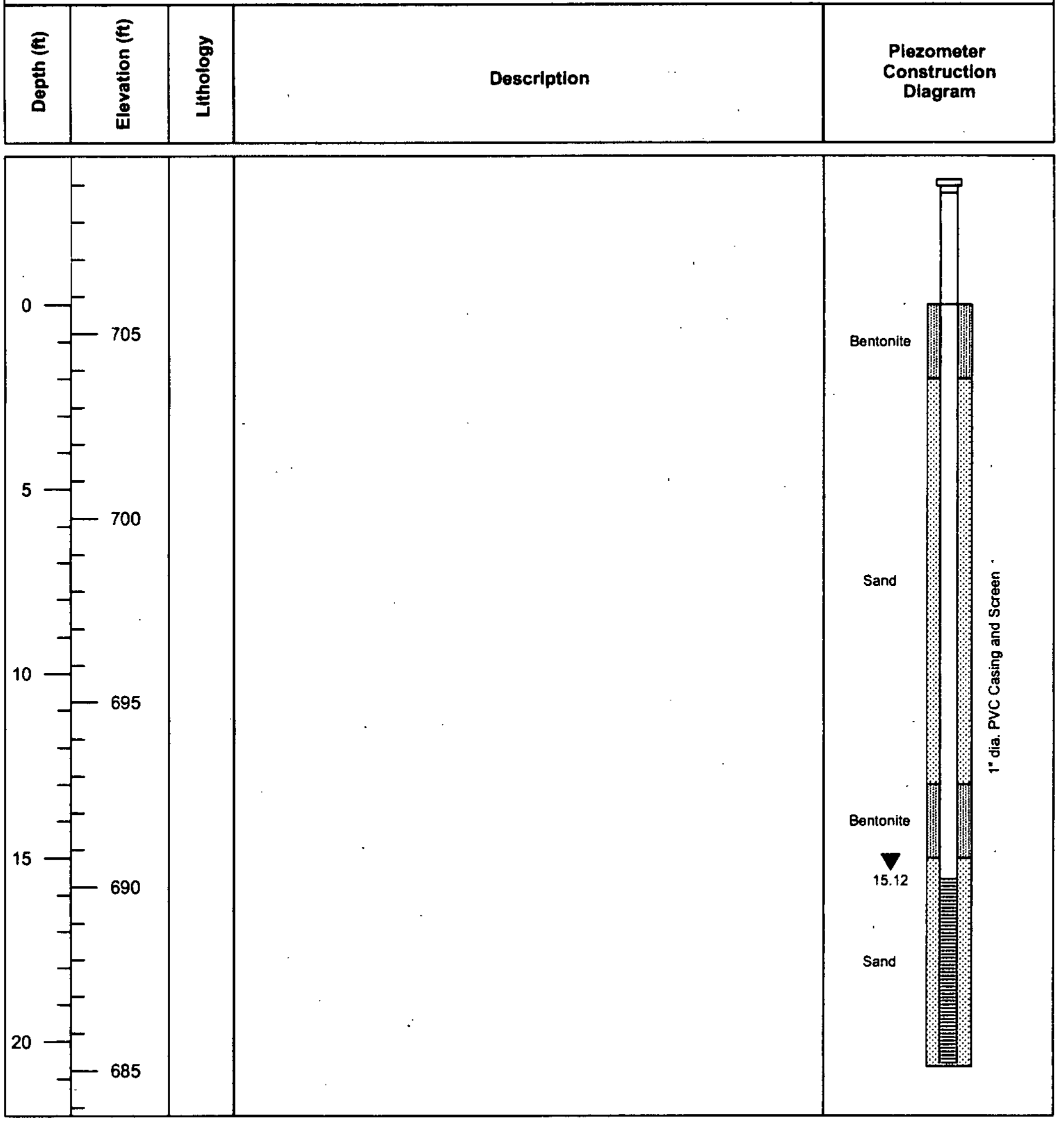
Depth (ft)	Elevation (ft)	Lithology	Description	Piezometer Construction Diagram



Project Name: Sequoyah Nuclear Plant	Drilling Date: 04/28/2004	Easting: 2270791.36
Company Name: TVA	Drilling Company: TVA	Northing: 304405.10
Location: South of Unit #2 Reactor Bldg	Drilling Method: Geoprobe	Top of Casing (ft): 708.11
	Well Depth (ft): 25.65	Top of Ground (ft): 704.8

TVA

Sequoyah Nuclear Plant **Boring ID: 35**

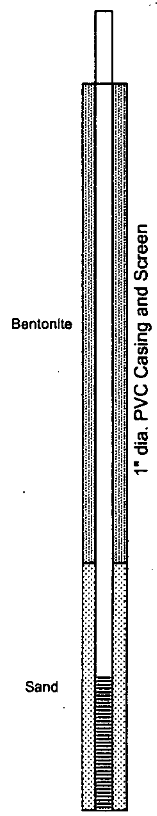


Project Name: Sequoyah Nuclear Plant	Drilling Date: 04/28/2004	Easting: 2270740.52
Company Name: TVA	Drilling Company: TVA	Northing: 304591.02
Location: South of Unit #2 Reactor Bldg	Drilling Method: Geoprobe	Top of Casing (ft): 708.87
	Well Depth (ft): 23.57	Top of Ground (ft): 705.78

TVA — Sequoyah Nuclear Plant — Boring ID: GP-7A

Depth (ft)	Elevation (ft)	Lithology	Description
0–3	705		Very soft to soft
3–25	700–685		Soft
25–26	680		Soft - Moderate
26–27			Moderate
27–31	675		Soft - Moderate
31			Stopped Boring at 31 ft

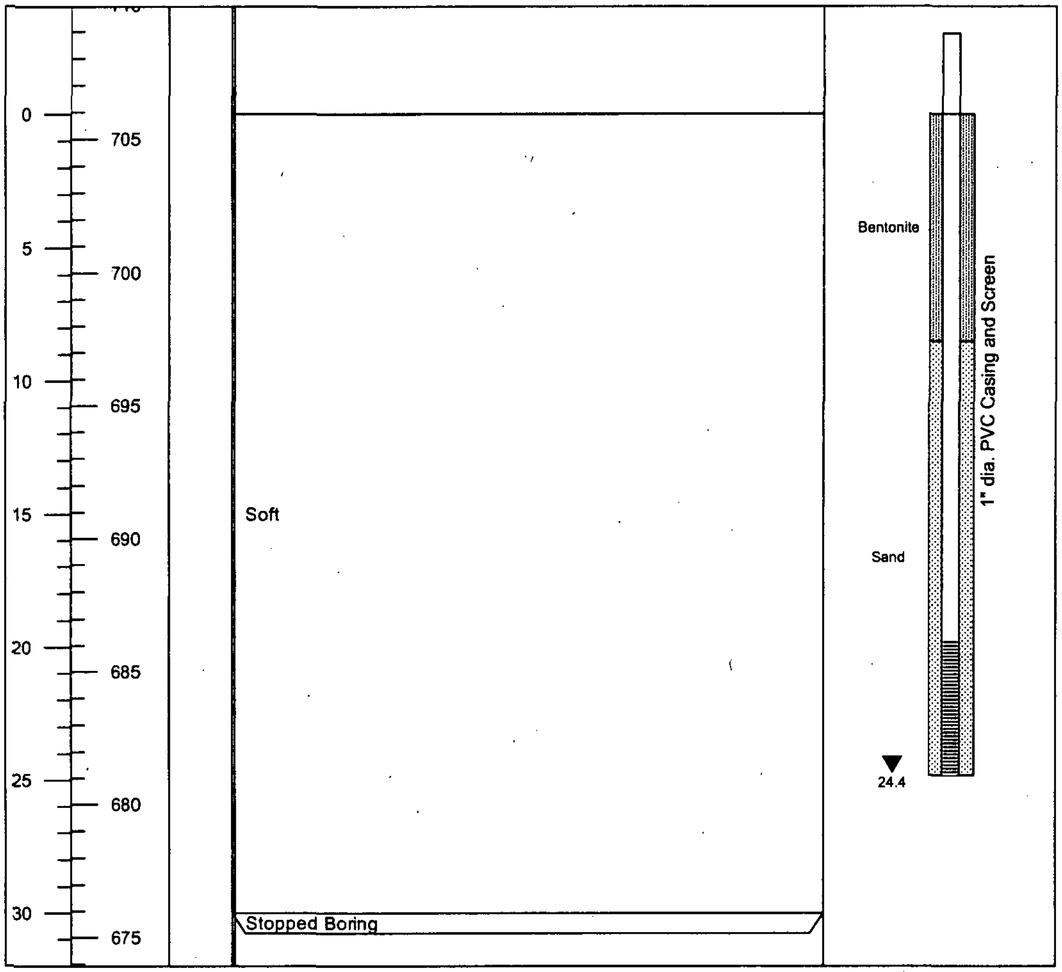
Piezometer Construction Diagram



Project Name:	SQN Tritium Investigation	Drilling Date:	2/16/2007	Easting:	2271466.20
Company Name:	TVA	Drilling Company:	TVA	Northing:	305423.58
Location:	North of Unit #1 Reactor Bldg	Drilling Method:	Geoprobe	Top of Casing (ft):	708.75
Driller/Engineer:	Ray Duncan/Matt Williams	Well Depth (ft) :	27.3	Top of Ground (ft):	706.05

Sequoyah Nuclear Plant **Boring ID: GP-7B**

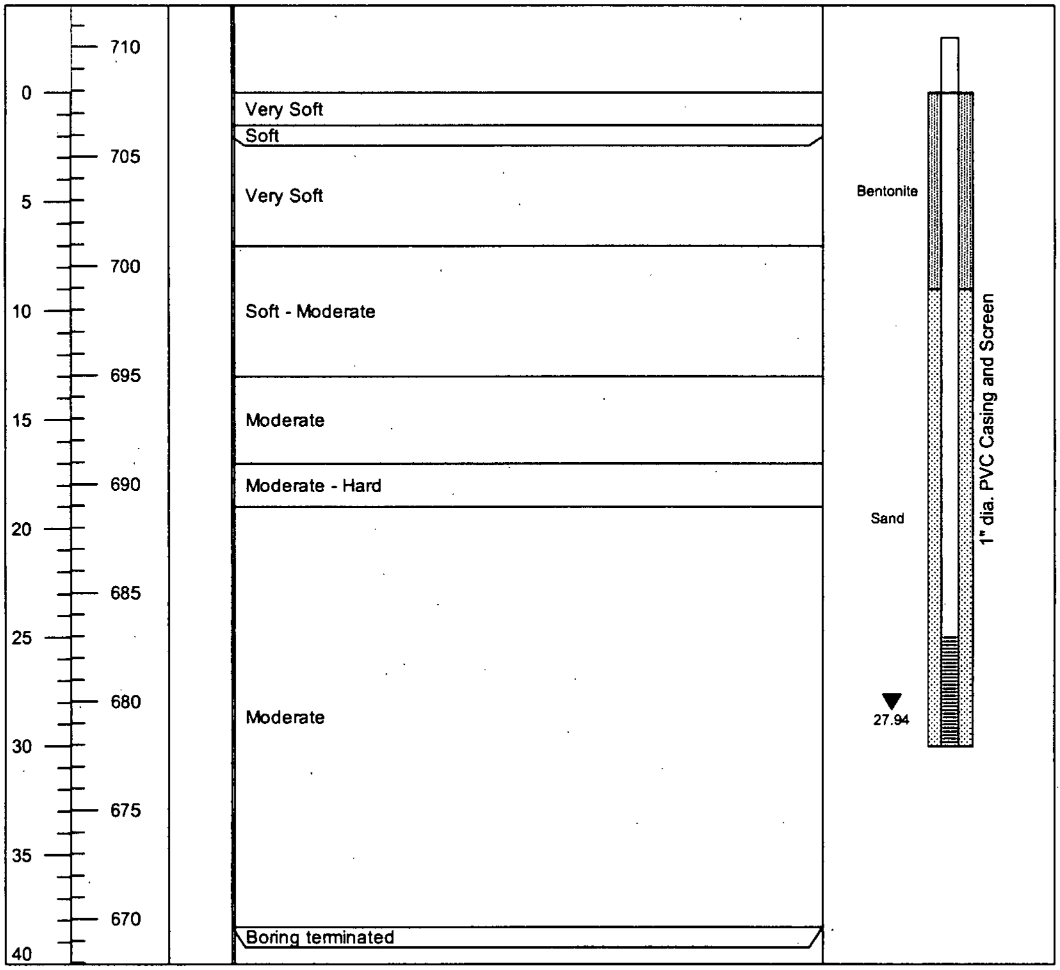
Depth (ft)	Elevation (ft)	Lithology	Description	Piezometer Construction Diagram



Project Name:	SQN Tritium Investigation	Drilling Date:	2/14/2007	Easting:	2271461.11
Company Name:	TVA	Drilling Company:	TVA	Northing:	305425.78
Location:	North of Unit #1 Reactor Bldg	Drilling Method:	Geoprobe	Top of Casing (ft):	708.93
Driller/Engineer:	Ray Duncan/Matt Williams	Well Depth (ft) :	24.8	Top of Ground (ft):	705.93

TVA	Sequoyah Nuclear Plant	Boring ID: GP-10

Depth (ft)	Elevation (ft)	Lithology	Description	Piezometer Construction Diagram



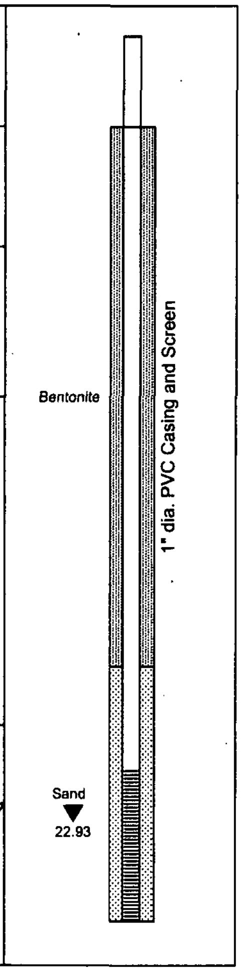
Project Name: SQN Tritium Investigation	Drilling Date: 2/1/2007	Easting: 2271866.70
Company Name: TVA	Drilling Company: TVA	Northing: 305237.90
Location: North of Unit #1 Reactor Bldg	Drilling Method: Geoprobe	Top of Casing (ft): 710.43
Driller/Engineer: Ray Duncan/Matt Williams	Well Depth (ft) : 30	Top of Ground (ft): 707.93

Sequoyah Nuclear Plant **Boring ID: GP-13**

Depth (ft)	Elevation (ft)	Lithology	Description
0–4	705–701		Soft
4–9	701–696		Moderate
9–20	696–685		Soft
20–22.5	685–682.5		Unknown Obstruction
22.5			Boring terminated - Unknown Obstruction

Depth scale: 0, 5, 10, 15, 20, 25; Elevation scale: 705, 700, 695, 690, 685, 680

Piezometer Construction Diagram



Project Name:	SQN Tritium Investigation	Drilling Date:	2/2/2007	Easting:	2271543.43
Company Name:	TVA	Drilling Company:	TVA	Northing:	305102.45
Location:	North of Unit #1 Reactor Bldg	Drilling Method:	Geoprobe	Top of Casing (ft):	708.34
Driller/Engineer:	Ray Duncan/Matt Williams	Well Depth (ft):	26.5	Top of Ground (ft):	705.34

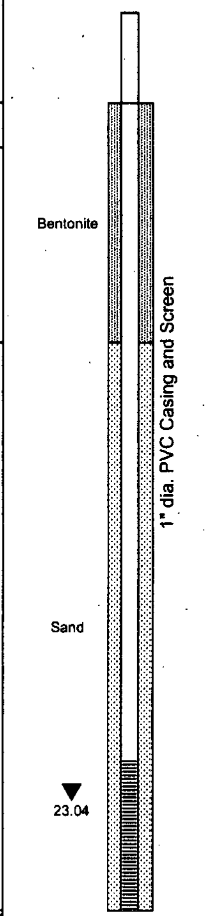
TVA

Sequoyah Nuclear Plant

Boring ID: GP-24

Depth (ft)	Elevation (ft)	Lithology	Description
0	705		Moderate
5	700		Soft
10	695		
15	690		Hard
20	685		
25	680		Boring terminated at 27 ft

Piezometer Construction Diagram



Project Name:	SQN Tritium Investigation	Drilling Date:	2/7/2007	Easting:	2271204.28
Company Name:	TVA	Drilling Company:	TVA	Northing:	304744.01
Location:	South of Unit #2 Reactor Bldg	Drilling Method:	Geoprobe	Top of Casing (ft):	707.94
Driller/Engineer:	Ray Duncan/Matt Williams	Well Depth (ft) :	27	Top of Ground (ft):	704.94

APPENDIX B

TRITIUM CONCENTRATIONS (pCi/L) FOR WELLS WITH MULTIPLE SAMPLES

	Tritium Concentration (pCi/L)													
Date	W21	24	25	26	27	28	29	30	31	32	33	34	35	GP-13
08/12/03					<220									
09/09/03					297									
10/07/03					339									
11/04/03					446									
12/02/03					407									
12/30/03					299									
01/27/04					371									
02/13/04	9,080													
02/24/04	9,000				285									
03/23/04					322									
03/31/04	1,524													
04/20/04					429									
05/18/04	1,116				277		1,006	<220	17,833	<220	<220	<220	<220	
06/15/04	1,138				293									
07/13/04	598	<220	<220	<220	257	<220								
08/02/04	961	<220	<220	<220	455	<220	1,034	<220	5,547	<220	<220	<220	<220	
09/07/04	1,050	<220	<220	<220	447	<220								
10/05/04	1,169	<220	<220	<220	334	<220								
10/12/04	1,261						791		3,768					
10/18/04	1,557						834		3,465					
10/26/04	1,633						914							
10/29/04	3,619													
11/01/04	2,270						819		2,646					
11/02/04	2,000	<220	<220	<220	385	<220								
11/08/04	2,492						1,191		3,094					
11/15/04	1,384						703		2,627					
11/22/04	1,712						753		2,576					
11/30/04	1,555						687		3,293					
11/30/04	2,216	<220	<220	<220	349	<220								
12/06/04	226						466		8,552					
12/13/04	586						606		7,053					
12/20/04	1,715						932		5,052					
12/27/04	1,954						622		7,306					
01/04/05	1,386						1,008		7,110					
01/10/05	1,947						1,027		5,938					
01/17/05	739						546		11,172					
01/24/05	2,178						1,239		9,841					
01/25/05	1,426	<220	<220	<220	303	<220								
01/31/05	526						554		10,780					
02/08/05	1,323						584		7,707					
02/14/05	427						702		5,600					
02/21/05	1,242						761		7,486					
02/22/05	1,216	<220	<220	<220	426	332								
02/28/05	739						953		8,589					
03/07/05	1,242						993		9,714					
03/14/05							652		9,354					

Date	Tritium Concentration (pCi/L)													
	W21	24	25	26	27	28	29	30	31	32	33	34	35	GP-13
03/21/05	2,763	<220	<220	<220	<220	<220	890		9,407					
03/28/05	492						948		8,898					
04/04/05	674						1,019		13,445					
04/11/05	562						742		12,824					
04/18/05	731						1,202		15,535					
04/25/05	967						1,326		17,011					
04/29/05	809								9,745					
05/02/05	1,796						1,465		9,532					
05/10/05	1,226						1,218		10,831					
05/16/05	974						1,050		11,604					
05/23/05	956						865		12,069					
05/30/05	2,773						881		12,372					
06/06/05	761						497		15,144					
06/14/05	404						555		19,750					
06/14/05	1,072	312	140	120	403	273								
06/21/05	985						771		19,545					
06/28/05	1,325						1,117		17,423					
07/05/05	1,038						1,390		15,900					
07/12/05	732	279	199	178	327	118	791		11,760					
07/18/05	372						514		11,593					
07/25/05	690						1,235		11,495					
08/01/05	1,447						1,224		10,199					
08/09/05	732	138	100	104	277	194	860		10,446					
08/15/05	941						866		10,928					
08/22/05	905						1,197		9,915					
08/29/05	1,945						1,177		8,968					
09/06/05	1,024	159	88	83	263	187	1,254		8,706					
09/19/05	1,139						869		7,765					
10/04/05	1,497						814		6,523					
10/17/05	1,146						819		5,936					
11/07/05	1,903						1,410		4,123					
11/29/05	1,118	205	112	80	478	168								
12/05/05	699						1,127		5,063					
12/12/05	850						1,007		5,609					
01/02/06	959						929		4,796					
01/16/06	841						1,029		6,081					
01/24/06	610	218	0	107	321	0								
02/06/06	662						987		5,613					
02/20/06	527						1,236		7,495					
02/21/06	531	148	51	18	177	67								
03/06/06	811						797		7,171					
03/21/06	1,069	118	7	0	203	21								
03/27/06	1,537						1,040		9,551					
04/03/06	630						1,170		11,780					
04/10/06	558				<270		1,228		17,544					
04/17/06	1,474				<270		1,049		10,645					

	Tritium Concentration (pCi/L)													
Date	W21	24	25	26	27	28	29	30	31	32	33	34	35	GP-13
04/18/06	968	235	<220	<220	245	<220								
04/24/06	1,644				<270		1,097		10,293					
04/27/06	1,208				<270		1,014		12,036					
05/01/06	1,536				<270		1,255		12,055					
05/04/06	758				<270		1,321		11,341					
05/08/06	1,780						1,377		10,380					
05/11/06	989						1,313		10,689					
05/15/06	2,059						1,479		11,763					
05/18/06	2,264						1,356		12,734					
05/23/06	763				<270		1,400		14,147					
05/25/06	1,097						968		16,191					
05/29/06	1,017				417		1,184		17,068					
06/01/06	1,134						1,274		15,708					
06/06/06	1,298				<270		1,119		13,955					
06/08/06	1,320						1,215		13,529					
06/12/06	1,494				<270		1,272		14,910					
06/13/06	1,193	<270	<270	<270	<270	<270								
06/22/06	1,604						1,221		13,531					
06/30/06	1,130				<270		973	<270	13,100	<270		<270		
07/03/06	1,365						1,226		12,974					
07/07/06	1,369				346		1,223		12,981					
07/11/06	1,371	<270	<270	<270	352	<270								
07/11/06	1,197						1,231		12,074					
07/13/06	1,325				<270		983		11,911					
07/18/06	1,534						1,262		11,509					
07/20/06	1,383				373		1,268		12,261					
07/24/06	784				<270		938		12,560					
07/31/06	1,067				<270		1,011		13,024					
08/07/06	1,000				<270		904		10,907					
08/08/06	997	<270	<270	<270	341	<270								
08/14/06	1,169				<270		932		9,838					
08/21/06	934				310		1,248		9,499					
08/28/06	2,188				<270		1,061		8,636					
09/05/06	1,251				<270		981		9,303					
09/05/06	1,570	<270	<270	<270	364	<270								
09/11/06	1,806				<270		1,332		8,787					
09/21/06	998				317		1,347		8,203					
09/26/06	455				<270		1,126		7,942					
10/02/06	704				<270		1,205		7,845					
10/03/06	1,276	<270	<270	<270	371	<270								
10/17/06	312				484		984		5,701					
10/25/06	570				<270		683		6,530					
10/30/06	649				<270		1,182		7,307					
10/31/06	844	<270	<270	<270	434	<270								
11/08/06	621				<270		1,174		7,087					
11/13/06	842				<270		1,144		5,583					

	Tritium Concentration (pCi/L)													
Date	W21	24	25	26	27	28	29	30	31	32	33	34	35	GP-13
11/22/06	794				<270		1,140		4,861					
11/28/06	799	<270	<270	<270	<270	<270								
11/29/06	985				301		1,433		4,026					
12/03/06									4,109					
12/04/06									4,373					
12/05/06	1,366				<270		1,169		4,456					
12/06/06									4,892					
12/07/06									4,619					
12/08/06									4,528					
12/09/06									5,632					
12/10/06									6,107					
12/11/06									7,124					
12/12/06	1,545				<270		1,067		6,017					
12/13/06									5,231					
12/14/06									4,071					
12/15/06									4,577					
12/16/06									4,135					
12/17/06									3,654					
12/18/06									3,702					
12/19/06	1,510				<270		806		3,718					
12/20/06									3,904					
12/21/06									3,983					
12/22/06									5,156					
12/23/06									8,214					
12/24/06									9,922					
12/25/06									11,497					
12/26/06	1,540	<270	<270	<270	369	<270			12,199					
12/27/06	1,526				<270		949		13,161					
12/28/06									13,766					
12/29/06									13,334					
12/30/06									13,592					
12/31/06									12,850					
01/01/07									12,620					
01/02/07									12,513					
01/03/07	908				<270		790		12,909					
01/04/07									12,702					
01/05/07									13,110					
01/06/07									10,809					
01/07/07									10,137					
1/8/107									9,236					
01/09/07	474				<270		739		9,336					
01/10/07									9,384					
01/11/07									8,748					
01/12/07									8,604					
01/13/04									9,083					
01/14/07									8,286					

	Tritium Concentration (pCi/L)													
Date	**W21**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**GP-13**
01/15/07									8,148					
01/16/07	869				<270		1,024		8,245					
01/17/07									9,445					
01/18/07									9,354					
01/19/07									8,990					
01/20/07									10,047					
01/21/07									10,763					
01/22/07	407				<270		885		7,736					
01/23/07	596	<270	<270	<270	<270	<270	<270		8,136					
01/24/07									8,032					
01/29/07	978				<270		763		9,373					
02/02/07														16,211
02/05/07	859				330		945		9,581					
02/12/07	1,196				<270		906		8,483					
02/16/07														17,604
02/19/07	1,359				299		828		7,309					
02/20/07	961	<270	<270	<270	<270	<270								
02/27/07	2,513				<270		611		7,549					18,395
03/06/07	1,386				<270		699		10,929					17,648
03/13/07	2,219				<270		839		10,855					17,584
03/19/07	1,343				<270		869		10,034					15,063
03/26/07	1,376						697		9,943					13,720