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Waste Treatment Area Investigation Report
General Electric - Wilmington, NC

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General Electric Company
Wilmington, North Carolina

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List of Acronyms and Abbreviations

CaF_2	Calcium fluoride
CEMQA	RTI Center for Environmental Measurements and Quality Assurance
DENR	North Carolina Department of Environment and Natural Resources
DO	Dissolved oxygen
EPA	Environmental Protection Agency
FSP	Field Sampling Plan
GE	General Electric
gpm	Gallons per minute
K	Hydraulic conductivity
K_d	Distribution coefficient
mg/L	Milligrams per liter
msl	Mean sea level
NCAC	North Carolina Administrative Code
ORP	Oxidation-reduction potential
PVC	Polyvinyl chloride
QA	Quality assurance
QAPP	Quality Assurance Project Plan
QC	Quality control
RTI	Research Triangle Institute
SOP	Standard operating procedure
TOC	Total organic carbon
WT	Waste treatment

Executive Summary

A hydrogeologic investigation recently conducted in the Waste Treatment area of the General Electric-Wilmington facility revealed a groundwater contaminant plume in the principal aquifer consisting of elevated concentrations of nitrate and ammonia. The plume is fully on site and does not pose a threat to neighboring properties or receptors. The suspected source of the contamination is leakage from one or both of two basins that contain a nitrate liquid. GE has addressed the suspected leakage by replacing the liners in both of these basins and by removing in-ground piping and a sump previously situated between the two basins. Investigation results suggest that natural attenuation of the nitrate plume may be occurring. Using natural-attenuation parameters that are reasonable for this geochemical system, fate and transport modeling predicts that the position of the nitrate contamination plume would be stable and that the maximum nitrate concentrations in groundwater would fall below the North Carolina groundwater standard within approximately 5 years. Contaminant transport modeling predicts that, if no natural-attenuation processes were occurring, the ammonia and nitrate plumes would be contained by GE's active pumping-well network. In this highly conservative scenario, the maximum nitrate concentration in groundwater is predicted to fall below the North Carolina groundwater standard within approximately 14 years. In addition to enhancements to the groundwater monitoring network, routine monitoring of groundwater and surface-water quality is recommended, along with regular reporting to the North Carolina Department of Environmental and Natural Resources.

The Research Triangle Institute (RTI) has prepared this area investigation report to address groundwater contamination identified near the Waste Treatment (WT) Facility of the General Electric (GE) site in Wilmington, North Carolina.

Waste Treatment Area Setting and History

The WT Facility became operational in 1972. There are four main elastomer-lined basins at the WT Facility. The two north basins contain a nitrate liquid. The two south basins hold a solid calcium-fluoride (CaF_2) material. As a voluntary measure, GE authorized RTI to conduct a hydrogeologic investigation of the WT area. In part, the investigation was designed to establish a baseline understanding of groundwater and surface-water quality before GE initiated removal of the CaF_2 from the two south basins. The preliminary findings of the assessment revealed a groundwater contaminant plume in the principal aquifer consisting of elevated concentrations of nitrate and ammonia. There is no evidence of impacts to groundwater quality from the CaF_2 basins. In response to these findings, GE authorized RTI to further investigate the nature and extent of the groundwater contamination.

The suspected source of the nitrate and ammonia found in groundwater is leakage from one or both of the two nitrate-liquid basins. Based on the chemistry of the nitrate liquid, the chemicals of concern with respect to potential environmental contamination are nitrate, ammonia, and uranium exhibiting non-natural isotopic ratios. However, only nitrate and ammonia are evident in groundwater at levels that indicate an anthropogenic source. GE has addressed the suspected leakage by replacing the liners in both of these basins and by removing in-ground piping and a sump previously situated between the two basins.

Geologic and Hydrogeologic Framework

The geologic units in the region consist of undifferentiated surficial deposits overlying the Castle Hayne and Peedee Formations. The Castle Hayne Formation has not been identified beneath the GE property.

Two aquifers exist beneath the WT Facility: within the surficial deposits exists a surficial aquifer under water-table conditions; an underlying principal aquifer exists under semiconfined conditions within the Peedee Formation. In most areas, these two aquifers are separated by a lower-permeability semiconfining layer.

The surficial aquifer in the WT area consists of highly stratified, heterogeneous, unconsolidated sands, silts, and clays. Generally, the surficial aquifer ranges from 6 to 10 feet thick. Groundwater flow patterns are complex and strongly influenced by surface topography and surface water (drainage ditches and an effluent channel). Overall, surficial-aquifer groundwater in the WT area discharges to the drainage ditches and the effluent channel, thereby mixing with surface water and ultimately flowing to the Northeast Cape Fear River.

Based on the results of the WT area investigation activities, the low-permeability, clayey, semiconfining layer between the surficial and principal aquifers appears to be present across most of the WT area. Despite observed heterogeneities, the semiconfining layer appears to effectively separate the two aquifers in most areas as demonstrated by the differences in groundwater elevations between the surficial and principal aquifers.

The principal aquifer consists primarily of fine to medium sand with some calcareous and glauconitic material and intermittent sandstone layers. Principal-aquifer groundwater flows generally to the north. Based on available data, groundwater flow in the principal aquifer across the WT area appears to be unaffected by the surface topography or positions of the drainage ditches.

Linear groundwater-velocity values were calculated for the principal aquifer in the WT area to be between 170 and 240 feet per year. Thus, the travel time between the WT basins and the leading edge of the nitrate plume (roughly 850 feet) is approximately between 3.5 and 5 years.

A numerical model of groundwater flow in the principal aquifer was developed to enhance the understanding of groundwater flow patterns and to allow predictions of the future behavior of groundwater constituents. The model indicates a travel time of approximately 4 to 5 years for groundwater to flow from the north edge of the WT Facility to the leading edge of the nitrate plume, which is consistent with the estimate calculated manually using Darcy's law. Once crossing the effluent channel, the groundwater is influenced by the capture zone of plant process-water wells and flows to the northeast toward these wells, which are not used for drinking-water supply.

Water-Quality Assessment

Although low levels of nitrate and ammonia have been detected in the drainage ditches surrounding the WT Facility, concentrations are currently below applicable regulatory levels.

Contamination in the surficial aquifer is restricted to a small area south of GE's WT Facility building. This contamination is attributed to historical surface releases, has been reported previously to the North Carolina Department of Environment and Natural Resources (DENR) by GE, and is not attributed to the nitrate basin leakage.

The approximate extent from the north edge of the east nitrate basin of principal-aquifer groundwater nitrate concentrations exceeding the North Carolina groundwater standard of 10.0 mg/L (as nitrogen) is 850 feet. Elevated levels of ammonia in principal-aquifer groundwater mostly mimic the nitrate pattern. However, ammonia has been detected slightly deeper and farther downgradient than has nitrate. Uranium detected in principal-aquifer groundwater north of the WT Facility demonstrates natural isotopic ratios. Therefore, these uranium detections are unrelated to the materials stored at the WT Facility. Although trace levels of fluoride have been detected in the principal aquifer in the area, none of the concentrations are above the 2.0 mg/L North Carolina groundwater standard.

Contaminant Fate and Transport

Nitrogen compounds like nitrate and ammonia can undergo a series of reactions, including denitrification, nitrification, nitrate reduction, and sorption. A series of analyses have been performed to evaluate the feasibility that these various reactions are occurring and to assess their importance on the potential attenuation and mobility of nitrate and ammonia in the WT-area principal-aquifer groundwater system. These analyses include development and use of a predictive transport model of the nitrate plume.

Geochemical, isotopic, and modeling results collectively suggest that natural attenuation of the nitrate plume may be occurring. In particular, the observation that the ammonia plume has migrated farther and deeper than the nitrated plume suggests that natural attenuation of the nitrate contamination is occurring.

Although specific mechanisms and their effectiveness remain uncertain, the most likely attenuation mechanism appears to be denitrification. Because the nitrate plume has only been monitored since 1998, the degree to which natural attenuation is limiting the nitrate contamination in the WT area needs to be better understood, as will be accomplished through continued monitoring.

Contaminant transport modeling predicts that, if no natural-attenuation processes were occurring, the ammonia and nitrate plumes would be contained by GE's active plant process-water well network north of the effluent channel. In this highly conservative scenario, concentrations of nitrate exceeding the North Carolina groundwater standard are predicted to reach GE's western process-water wellfield within 5 years, and would attenuate to levels below this regulatory standard within approximately 14 years.

Using natural-attenuation parameters that are reasonable for this geochemical system, fate and transport modeling predicts that the current position of the nitrate plume would be stable and would degrade to below the North Carolina groundwater standard within approximately 5 years.

The uranium component of the released nitrate liquid apparently has been effectively attenuated by the geologic materials situated between the basins and the principal aquifer.

Potential Receptors

There are no identified potential drinking water receptors to the groundwater contamination. The only potential receptors of the contamination would be workers that come in contact with groundwater produced from on-site monitoring wells and, potentially, the westernmost on-site wells in GE's plant process-water wellfield. Because the nitrate liquid treated at the WT Facility contains higher levels of nitrate than the groundwater, no additional potential risk is introduced to workers who may come into contact with the groundwater pumped from on-site monitoring wells or process-water wells.

An evaluation of potential surface-water receptors was not performed because concentrations of the measured chemicals in surface water are currently below applicable regulatory levels.

Recommendations

It is recommended that GE continue the routine monitoring program as described in the Sampling and Analysis Plan attached to this report. This monitoring will enable GE and RTI to:

- Verify numerical flow-model predictions;
- Update the contaminant transport modeling predictions of future plume configurations;
- Monitor for any potential breakthrough of uranium; and
- Identify if an evaluation of additional remedial measures is warranted.

To enhance the monitoring network, construction of two new surficial-aquifer monitoring wells is currently being completed, and it is recommended that three new principal-aquifer monitoring wells be constructed. Annual reports to the DENR Groundwater Section that present the results of the routine monitoring events are also recommended. These reports will describe any changes to the interpretations and predictions presented in this area investigation report, and will present recommendations for monitoring-program modifications or for an evaluation of additional remedial measures, as appropriate.

1.0 Introduction

The Research Triangle Institute (RTI) has prepared this area investigation report to address groundwater contamination identified near the Waste Treatment (WT) Facility of the General Electric (GE) site in Wilmington, North Carolina. The following sections provide background information for the WT Facility and a description of the materials treated and stored at the Facility.

1.1 Waste Treatment Area Setting and History

The WT Facility is located in the south-central portion of the GE-Wilmington property, which encompasses approximately 1,664 acres (Figure 1-1). The GE-Wilmington facility is located on US Highway 117 approximately 6 miles north of Wilmington and approximately 3 miles south of Castle Hayne, North Carolina. The property extends from US Highway 117 west to the Northeast Cape Fear River. There are currently two principal manufacturing activities located at the GE-Wilmington site: nuclear fuel and components, and aircraft engine parts. Approximately 350 acres of the southern and eastern area of the GE site are currently developed (GE, 1989).

The WT Facility became operational in 1972. The base map shown in Figure 1-2 is an aerial photograph of the WT Facility taken in March 1996. There are four main elastomer-lined basins at the WT Facility. The two north basins contain a nitrate liquid. GE replaced the liners in the two north basins in late 1998 and mid 1999, respectively. The two south basins hold a solid calcium-fluoride (CaF_2) material, a by-product of the nuclear fuel manufacturing process.

GE is in the process of eliminating the generation of the CaF_2 material and is currently removing the CaF_2 that has accumulated in the WT basins by pumping the CaF_2 slurry to a filter-press operation constructed southwest of the WT Facility. GE has initiated a program to monitor surface water and groundwater before, during, and after the CaF_2-removal operation. The CaF_2-removal monitoring program is not discussed further in this report.

A recent hydrogeologic investigation, further described in Section 2.0, included collection of groundwater samples from the surficial and principal aquifers in the WT area for analysis of total uranium, fluoride, ammonia[1], and nitrate. The findings of this study revealed a groundwater contaminant plume in the principal aquifer consisting of elevated concentrations of nitrate and ammonia. Leakage from one or both of the two north basins holding the nitrate liquid is the suspected source of the nitrate and ammonia found in groundwater. GE has addressed the suspected leakage by replacing the liners in both of these basins and by removing in-ground piping and a sump previously situated between the two north basins. The two south basins are not suspected sources of the principal-aquifer contamination because the chemicals of concern associated with CaF_2, primarily fluoride and uranium exhibiting non-natural isotopic ratios, have not been identified in principal-aquifer groundwater at elevated levels. Because the discovered principal-aquifer contamination apparently is unrelated to the CaF_2 stored in the two south basins or the current CaF_2-removal operation, this area investigation report primarily focuses on the nitrate liquid and the associated ammonia and nitrate groundwater contamination.

1.2 Nitrate Liquid Characterization

The nitrate liquid is accumulated at the GE facility primarily from uranyl nitrate conversion, acid flushing of process equipment, and a solvent-extraction process. The primary impurities in this liquid are ammonium nitrate, nitric acid, and uranium exhibiting non-natural isotopic ratios. This liquid also contains the impurities that have been removed from uranium compounds in the scrap processing operation. The treatment steps are designed to sequentially recover the uranium compounds present and then remove the other impurities while retaining the ammonium nitrate in solution. The bulk of the uranium removal is accomplished in the fuel manufacturing area. The nitrate liquid is then transferred via pipeline to the WT Facility where lime is added to precipitate residual impurities. The solids are then removed by a filtration process. The remaining solution is pumped to the two north WT Facility basins for storage until the liquid is transferred by tank

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[1] As discussed in Section 5.1.2, ammonium (NH_4^+) and ammonia (NH_3) generally exist in equilibrium with each other in the environment. Considering the pH of the groundwater system being investigated, the ammonium ion should be the predominant species. However, the laboratory analytical method employed for this investigation first converts all the ammonium in the sample to ammonia before quantitation, and the result is reported as total ammonia nitrogen. Therefore, throughout this report, reference to "ammonia" in groundwater is intended to imply the combined presence of dissolved ammonia and ammonium.

truck to a paper manufacturer (Federal Paper Board Company, Inc., in Riegelwood, NC) for beneficial utilization in their biological waste treatment process.

Table 1-1 presents a summary of the chemical characteristics of the nitrate liquid. Average concentrations are presented for chemical measurements performed from 1989 through 1995 by GE on the nitrate liquid shipped to the paper manufacturer. In addition, analytical results for samples collected by RTI during the recent area investigation also are shown in Table 1-1. Considering these results, the chemicals of concern with respect to potential environmental contamination from the nitrate liquid are nitrate, ammonia, and uranium exhibiting non-natural isotopic ratios because these are the only chemicals present at concentrations notably higher than regulatory standards.

2.0 Summary of Waste Treatment Area Investigation Activities

As a voluntary measure, GE authorized RTI to conduct a hydrogeologic assessment of the WT area which was, in part, designed to establish a baseline understanding of groundwater and surface-water quality before the CaF_2 removal operation began. Additionally, GE requested that RTI initiate a routine water-quality monitoring program to be conducted during and after the CaF_2-removal process. As discussed in Section 1.1, the preliminary findings of the assessment revealed a groundwater contaminant plume in the principal aquifer consisting of elevated concentrations of nitrate and ammonia. In response to these findings, GE authorized RTI to further investigate the nature and extent of this contamination. Table 2-1 summarizes the activities conducted for this investigation as well as historical activities pertinent to the content of this report. Figure 1-2 shows the locations where most of these activities took place. In addition to the replacement of the liners in the northeast and northwest basins, discussed in Section 1.1, most of the activities listed in Table 2-1 fall into the categories of hydrogeologic and water-quality evaluations, as described below. Section 3.0 presents a detailed discussion of the geologic and hydrogeologic framework briefly referenced in the following paragraphs.

2.1 Monitoring-Well Construction

Prior to the recent area investigation, three series of monitoring wells were constructed from 1972 to 1990: the initial WT-series wells, the MW-series wells, and the CW-series wells. The recent area investigation included construction of seven additional surficial-aquifer monitoring wells and seven additional principal-aquifer monitoring wells. Construction of three more principal-aquifer monitoring wells is currently pending. Table 2-2 summarizes well-construction details for all the WT-area monitoring wells.

The recently-installed monitoring wells were constructed using hallow-stem augers to drill through the surficial aquifer, and rotary drilling (potable-water used as the drilling fluid) to drill through the semiconfining layer and into the principal aquifer. Downhole drilling equipment was decontaminated using a high-pressure cleaner before and after each well was drilled. The wells were constructed with 2-inch-diameter, polyvinyl chloride (PVC), screens and riser pipe. Principal-aquifer wells also have either a 6-inch or 8-inch diameter, schedule-40, PVC surface casing installed through the surficial aquifer and seated into the semiconfining layer. The annular space outside surface casings is sealed with cement grout. The well screens have 0.01-inch slots and range in length from about 2 to 10 feet. The annular materials installed between the 2-inch diameter well string and the borehole and, for principal-aquifer wells, between the 2-inch diameter well string and the surface casing, consist of: a) sandpack extending from the total drilled depth to at least 1 foot above the top of the screen; b) bentonite from the top of the sandpack to approximately 1 foot above the top of the semiconfining layer for principal-aquifer wells and at least 0.5-foot thick for surficial-aquifer wells; and c) cement grout from the bentonite layer to the ground surface. The wells were completed with a concrete apron and protective casing with locking cap. Each new monitoring well was developed until the water was visually free of turbidity or as appropriate based on professional judgement. A registered land surveyor measured the elevation of the top of each new 2-inch diameter well casing (water-level measuring point) to the nearest 0.01 foot. In addition, the surveyor measured the ground surface elevation and the northing and easting coordinates for each well.

2.2 Piezometer Installation

Nineteen piezometers were installed within the surficial aquifer during the recent area investigation. Table 2-3 summarizes the construction details for these piezometers. The piezometers were installed using a Geoprobe-type direct-push sampling rig. At each piezometer location, soil samples were collected using 2-inch diameter Macro Core Samplers continuously from the ground surface until the semiconfining clay layer at the base of the surficial aquifer was observed. A 2⅛-inch outside-diameter probe rod and expendable anchor point then were advanced to the completion depth. The piezometer was constructed inside the probe rod with the following materials as the probe rod was withdrawn:

- *Three-foot long section of Geoprobe prepacked screen secured to the expendable drive point.* These prepacked screens have an outside diameter of 1.5 inches and an inside diameter of 0.5 inches. The inner component of the prepacked screen consists of 0.5-inch Schedule 80 PVC with 0.01-inch slots. The outer component of the screen is stainless-steel wire mesh with a pore size of 0.11 inches. The screens are prepacked with 20/40 grade silica sand. Generally, the bottom of each piezometer screen was placed within 1 foot of the top of the semiconfining layer.

- *Riser pipe sections with vented top cap.* 0.5-inch inside diameter Schedule 80, PVC, flush-threaded riser pipe with vented top caps extend from the top of the screens to approximately 1 foot above ground surface.

- *Filter pack and annular seal.* Granular bentonite was placed above the pre-packed screen to approximately 6 inches below ground surface.

The Macro Core Sampler, associated sampling tools, and Geoprobe drive rods were decontaminated before and after each piezometer was installed using a solution of laboratory-grade detergent (e.g., Alconox) and/or high-pressure cleaning equipment. The piezometers were completed with a concrete apron and protective casing with locking cap and were developed and surveyed as described in Section 2.1.

2.3 In-Situ Water Sampling from Soil Borings

In order to further characterize the lateral extent of groundwater contamination, in-situ groundwater samples were collected from soil borings advanced into the principal aquifer at eight locations. In-situ groundwater samples were collected at six additional locations to further characterize both the lateral extent and vertical distribution of groundwater contamination. Boring specifications, including groundwater sampling depths, are summarized in Table 2-4. In-situ groundwater samples were collected using a Geoprobe Screen Point 15 Groundwater Sampler. For this sampling technique, boreholes first are created using the Geoprobe equipment described in Section 2.2. Once the target depth has been reached, the sampling device is lowered to the bottom of the probe hole and driven its full 4-foot long length into the undisturbed principal-aquifer sediment. While the screen is held in place with the extension rod, the tool string is pulled back to expose approximately 1 foot of the screen. Using dedicated tubing and a peristaltic pump, groundwater samples then are collected in appropriate containers with applicable preservatives for the selected analytes. As shown in Table 2-4, at several locations the probe holes were re-drilled for construction of a new monitoring well. Other probe holes were sealed with bentonite after sampling was completed.

2.4 Stream-Gauge Construction

A stream gauge was constructed at seven locations shown in Figure 1-2. The stream gauges enable manual stage elevation measurements to the nearest 0.01 feet. The stream gauges consist of a piece of steel angle iron driven directly into the bottom of the drainage ditch or effluent channel. Generally, the completed installation extends approximately 3 to 4 feet above the channel/ditch bed. A fiberglass measuring tape graduated in 0.01-foot increments is attached to the angle iron for direct reading of the water level. At each stream-gauge location, a concrete monument was established adjacent to the staff gauge out of the channel/ditch. Elevations above mean sea level (msl) of each concrete monument and the top of each staff gauge were measured by a professional land surveyor. When staff gauges shift and are repaired, the new elevations are established directly from the adjacent concrete monument.

2.5 Surface-Water and Groundwater Sampling

Several surface-water and groundwater sampling events were conducted during the recent area investigation, and a subsequent routine monitoring program has been implemented. Of the principal-aquifer monitoring wells included in the routine sampling events, all are screened within the upper portion of the aquifer (well names with the suffix "B") except monitoring well WT-7C and process-water well WW-14, which are screened deeper within the principal aquifer. Appendices A and B are a Field Sampling Plan (FSP) and a Quality Assurance Project Plan (QAPP) (RTI Report Nos. 6448-020/002/01F and 6448-020/003/01F, respectively) prepared for the routine monitoring program. The previously performed sampling events were conducted in general accordance with the procedures described in these plans. Included in the FSP are several Standard Operating Procedures (SOPs) that describe how RTI collects surface-water and groundwater samples.

3.0 Geologic and Hydrogeologic Framework

The GE site is located in the northwest portion of New Hanover County in North Carolina. Elevations in this region of the Atlantic Coastal Plain generally range between 0 and 50 feet msl. The next sections describe the geologic and hydrogeologic features and attributes of the region and the investigation area.

3.1 Regional Geology and Hydrogeology

A geologic cross section through New Hanover County is provided in Figure 3-1. The Northeast Cape Fear River represents a major hydrogeologic feature in the region. The geologic units in the region consist of undifferentiated surficial deposits overlying the Castle Hayne and Peedee Formations. These units are described below.

3.1.1 Surficial Deposits. The upland portions of the region, generally between 20 and 40 feet msl, are underlain by highly stratified, undifferentiated deposits of late Tertiary/Quaternary age. These surficial deposits primarily include terraced and barrier beach deposits, fossil sand dunes, and stream channel deposits. The surficial deposits in the region typically include medium to fine-grained sands, clayey sands, silts, and clays. Peat is also present intermittently in these deposits, and coarse-grained sands are found in some areas where channels of the Northeast Cape Fear River once flowed.

The more permeable surficial deposits form a surficial aquifer. The surficial aquifer is recharged directly by rainfall, and the water table is typically near the land surface. Discharge of the aquifer is into streams and drainage canals and, in some areas, into underlying aquifers (Le Grand, 1960). The silty and clayey deposits that underlie the surficial aquifer in most of the region form a semiconfining bed to the underlying aquifers.

3.1.2 Peedee Formation. The Peedee Formation of Upper Cretaceous age forms an aquifer consisting of unconsolidated greenish-gray to dark-gray silt, olive-green to gray sand, and massive black clay. These materials are interbedded with consolidated calcareous sandstone and limestone. The upper portion of the formation has more sand and lime content than the base of the formation (Bain, 1970). The sand within the formation is fine- to very fine-grained subangular quartz with trace quantities of glauconite and other minerals. The Rocky Point Member of the Peedee Formation contains very calcareous sandstone and sandy limestone with abundant molds and casts (Zarra, 1991). The top of the formation dips to the east-southeast in New Hanover County.

Figure 1-1 shows the approximate western extent of the more permeable, upper sandy portion of the Peedee Formation (after Bain, 1970). This boundary crosses through the GE-Wilmington facility with most of the WT investigation area positioned on the eastern, more permeable side.

3.1.3 Castle Hayne Formation. The surficial deposits are underlain by the Castle Hayne Formation of Eocene age in the eastern part of New Hanover County. The Castle Hayne Formation consists primarily of shell, marl, sand, and limestone. The distribution and thickness of the formation is irregular, resulting from its deposition on the eroded surface of the Peedee Formation. The Castle Hayne Formation does not appear to be present beneath the GE property on the basis of lithologic observations from site borings (i.e., the absence of significant deposits of shell, marl, and/or limestone) and on the basis of recently mapped stratigraphy of the region by Zarra (1991).

3.2 Hydrogeology of the Waste Treatment Area

Two aquifers exist beneath the WT Facility: a surficial aquifer under water-table conditions exists within the surficial deposits; an underlying principal aquifer exists under semiconfined conditions within the Peedee Formation. These two aquifers are separated by a lower-permeability semiconfining layer. Figures 3-2 and 3-3 are cross sections through the WT area showing the mapped configuration of these hydrogeologic features, which are further discussed below. The geologic information used to generate these cross sections was interpreted from the lithologic logs generated while drilling wells and borings in the investigation area. Appendix C contains lithologic logs generated during the recent investigation and available logs for other locations shown in Figure 1-2.

3.2.1 Surficial Aquifer. The surficial aquifer in the WT area consists of highly stratified, heterogeneous, unconsolidated deposits of coarse to fine-grained sands, clayey sands, silts, and clays. Generally, the surficial aquifer ranges from 6 to 10 feet thick, but is dissected in places by two types of surface water features in the WT area: drainage ditches and the effluent channel (Figure 1-2). Before the WT Facility was constructed, there were no natural stream channels at that location. In order to protect the WT Facility berm from erosion by stormwater, drainage ditches were excavated around the base of the berm at the time the Facility was constructed in order to collect stormwater runoff from the surrounding area. The excavated depth of these drainage ditches penetrated the water table, and surficial-aquifer groundwater now seeps into these ditches (the drainage ditches have become "gaining streams"). The effluent channel is situated along a pre-existing surface-water feature that deeply dissects the surficial aquifer, and surficial-aquifer groundwater discharges into this feature. Historically, GE dredged the bottom of the channel thus extending its depth, but some of that excavation has since been re-filled with alluvial deposits.

Figure 3-4 is a water-table map prepared from water-levels measured on May 5, 1999, in surficial-aquifer monitoring wells and piezometers and at stream gauging stations. As this figure shows, groundwater flow patterns in the surficial aquifer are complex. The patterns are strongly influenced by surface topography and positions of drainage ditches and the effluent channel. Water levels in the surficial aquifer readily rise and fall in response to precipitation events, and some small-scale variations in flow patterns have been observed. Overall, however, surficial-aquifer groundwater discharges to the drainage ditches and the effluent channel, mixes with surface water, and ultimately flows to the Northeast Cape Fear River.

At a meeting held on June 10, 1999, with the North Carolina Department of Environment and Natural Resources (DENR), Groundwater Section, one of the topics discussed was the possibility that the mounding pattern typically observed in the surficial aquifer beneath the WT Facility might be due to leakage from one or both of the lined WT basins. In response to this hypothesis, RTI further studied the soils and groundwater levels in the WT area; this study is discussed in greater detail in the July 9, 1999, memorandum included in Appendix D. On the basis of that study, it was interpreted that the position of the drainage ditches surrounding the WT Facility, not leakage from the lined basins, is the primary cause of the mounding pattern -- it is inferred that the presence of the drainage ditches causes the water table to be deflected downward toward the elevation of the ditches. Figure 3-5 is a cross section through the northeast corner of the WT Facility that illustrates how the water table is influenced by topography and the drainage channels.

3.2.2 Semiconfining Layer. Based on the results of the WT area investigation activities, the low-permeability, clayey, semiconfining layer between the surficial and principal aquifers appears to be present across most of the WT area with the elevation of the top of the layer ranging between 15 and 26 feet msl. The thickness and elevation of the semiconfining layer is shown in cross section on Figures 3-2 and 3-3. These depictions were generated using a linear kriging interpolation procedure on the lithologic data included in Appendix C. Similarly, Figure 3-6 is a map view of the WT area showing the thickness of the semiconfining layer generated using this geostatistical technique. The thickness and continuity of the semiconfining layer is inconsistent in places. For example, near well WT-4 the semiconfining layer consists of two clayey strata that each are approximately 1.5 feet thick and are separated from each other by about 3 feet of sand. In contrast, northwest of the WT Facility, an approximately 12-foot thick continuous, competent, clay layer was observed (boring WTB-25). Figure 3-5 illustrates the variability observed in the number, thickness, and elevations of clay layers across the northeast corner of the WT Facility. Despite these heterogeneities, the semiconfining layer appears to effectively separate the surficial and principal aquifers in most areas as demonstrated by the differences in groundwater elevations between the surficial and principal aquifers (Figures 3-4 and 3-7).

3.2.3 Principal Aquifer. The principal aquifer consists primarily of fine to medium sand. At depth, the sand becomes finer and glauconitic. Intermittent calcareous sandstone layers are encountered at elevations of about -10 to -20 msl (about 40 to 60 feet below ground surface in the WT area). As shown in the cross section on Figure 3-2, the original dredged depth of the effluent channel is interpreted to have breached the semiconfining layer in the downstream portion of the WT investigation area thus likely placing alluvial channel-fill deposits in contact with the principal aquifer at those locations.

3.2.3.1 Principal-Aquifer Groundwater Flow Directions. Figure 3-7 shows elevations of the principal-aquifer potentiometric surface measured on May 5, 1999, along with groundwater flow directions indicated by these data. Principal-aquifer groundwater flows generally to the north, consistent with interpretations developed for other projects on the GE-Wilmington site. Based on available data, groundwater flow in the principal aquifer appears to be unaffected by the surface topography or positions of the drainage ditches. Water-level measurements performed during the investigation reveal a hydraulic gradient between the principal aquifer potentiometric surface and the surface-water level in the effluent channel. Because the semiconfining layer is thin to absent below the effluent channel, it is interpreted that water seeps from the effluent channel into the principal aquifer or vice versa, depending on the direction of the hydraulic gradient. Upstream of the WT investigation area, the effluent-channel water level is higher than the potentiometric surface (downward gradient), thus indicating a losing stream (surface water seeps into the principal aquifer). Downstream of the WT investigation area, the potentiometric surface is higher than the effluent-channel water level (upward gradient), thus indicating a gaining stream (principal-aquifer groundwater discharges to the effluent channel). As is further discussed in Section 3.2.3.3, the amount of water seeping between these two bodies is inferred to be relatively small, particularly across the WT investigation area where the gradients reverse in direction and are small in magnitude. This assessment is supported by the potentiometric surface mapped across the WT investigation area (Figure 3-7) which does not reveal an observable impact by the effluent channel on principal-aquifer groundwater flow patterns. The effluent channel is inferred to have an observable effect on the potentiometric surface downstream of the WT investigation area, as described in Section 3.2.3.4. As will be discussed in Section 4.2, water-quality data also do not show an observable effect from this hydraulic connection.

3.2.3.2 Hydraulic Conductivity Measurements. Hydraulic conductivity is a critical parameter for understanding groundwater flow patterns and for estimating groundwater flow velocities. This section describes the hydraulic conductivity estimates and the flow-velocity calculations for the principal aquifer in the WT area.

Estimates for hydraulic conductivity were developed using existing knowledge of the GE site (including slug tests, grain size analyses, and pumping tests performed in other areas of the site) as well as measurements performed within the WT area. The hydraulic conductivity measurement in the WT area involved pneumatic slug testing of 12 wells screened in the principal aquifer. Appendix E describes the pneumatic slug-test method and the testing results in detail. Table 3-1 presents a summary of the slug-testing results in the WT area. As this table indicates, the hydraulic-conductivity estimates vary from 4 to 34 ft/day, and the overall geometric means calculated using two analytical methods are 11 and 17 ft/day. Also, it is apparent that the hydraulic conductivity generally decreases with depth in the principal aquifer. The geometric-mean hydraulic-conductivity value for the deeper wells (those screened completely below mean sea level) varies from 6 to 8 ft/day, while the geometric mean for the shallower wells varies from 15 to 24 ft/day.

Hydraulic conductivity results from other areas of the GE site indicate that there is a general decreasing trend in hydraulic conductivity from the west to east across the facility. For example, two analytical procedures applied to slug-testing data generated in the northwest area of the GE facility indicate geometric-mean hydraulic-conductivity values of 1 and 3 ft/day (RTI, 1998; RTI, 1999). In contrast, pumping tests in recovery well WW-9A (approximately 3000 feet east-northeast of the WT area) indicate a hydraulic conductivity in the 40 feet/day range (RTI, 1996). The hydraulic conductivity measurements for the WT area (Table 3-1) fall between the ranges measured for the western and the eastern areas of the GE facility. This observation agrees with the assessment by Bain (1970) that there is a regional geologic contact dividing the portion of New Hanover County where the GE site is located, as shown in Figure 1-1. To the east of this contact, the principal aquifer corresponds to the more permeable, upper sandy portion of the Peedee Formation, identified as "Sandstone Aquifer" on the cross section shown in Figure 3-1. The conductivity is correspondingly in the upper range of measured values for the site. To the west of this geologic contact, the conductivity decreases as the upper sandy portion of the Peedee Formation pinches out and the principal aquifer has an increasing silt and clay component.

3.2.3.3 Groundwater Flow Velocity Calculation. Linear groundwater velocity, v, in the WT area is estimated to be between 170 and 240 ft/year. Thus, the travel time between the WT basins and the leading edge of the nitrate plume (roughly 850 feet) is approximately between 3.5 and 5 years. This travel-time estimate is applicable to groundwater rather than contaminants dissolved in the groundwater. Reactive groundwater contaminants, such as those described in this report, typically require a longer time to travel this distance. The groundwater-velocity values were calculated using Darcy's law, expressed by the following equation:

$$v = \frac{Ki}{n}$$

where:

> K is the hydraulic conductivity (ft/day): averaging the two hydraulic-conductivity geometric-mean values calculated shown in Table 3-1 for the shallower portion of the principal aquifer, a value of 20 ft/day is estimated to be representative for the portion of the principal aquifer in the WT area affected by nitrate contamination;
>
> i is the hydraulic gradient (unitless): the hydraulic gradient measured for the principal-aquifer potentiometric surface across the WT investigation area varies approximately between 0.007 and 0.01;

and

n is the effective porosity (unitless): a value of 0.3 for effective porosity is a typical value for fine to medium sands (Fetter, 1988).

3.2.3.4 Modeling of Principal-Aquifer Groundwater Flow. A numerical model of groundwater flow in the principal aquifer was developed to enhance the understanding of groundwater flow patterns and to allow predictions of the future behavior of groundwater constituents. Appendix F provides a more detailed description of the flow-model development and results. Model reliability was improved by accurately calibrating the model to measured groundwater elevations as described in Appendix F. This section provides an overview of the model and presents some of the general model results.

In order to properly describe flow in the principal aquifer in the WT investigation area, the relevant regional hydrogeologic boundary conditions were included in the model domain. Appendix F provides a detailed discussion of the boundary conditions established for the model. The primary input of groundwater to the system is recharge from leakage through the overlying semiconfining unit and from direct seepage of rainwater in areas where the semiconfining unit is absent (e.g. in the northwest portion of the GE property). In general, groundwater enters the system through recharge and flows outward toward the hydrogeologic boundaries, including streams and the low-lying swampy area that surrounds much of the region.

Groundwater in the principal aquifer does not interact with most surface streams at higher elevations because the stream beds are separated from the aquifer by the less permeable semiconfining unit. However, at lower elevations, the streams have incised through the semiconfining unit and are in direct connection with the principal aquifer. Therefore, the principal aquifer groundwater elevations typically are influenced by surface streams only at lower elevations. Due to historical dredging of the original streambed, the effluent channel is the only known exception to this pattern. As discussed in Section 3.2.3.1, the effluent channel is understood to be a losing stream east (upstream) of the WT investigation area and a gaining stream west (downstream) of the WT investigation area. Therefore, the model has been constructed to represent the effluent channel as a river boundary, which can lose and/or gain groundwater to or from the system. The results of the model indicate that the point where the effluent channel changes from a losing stream to a gaining stream is approximately in the area of well WT-17B. The rates of flow between the principal aquifer and the effluent channel are relatively small. Upstream of the WT-17B area, the flow from the effluent channel into the principal aquifer is estimated to range from 2 to 10 gallons per minute (gpm) per 100 feet of channel length. Downstream of the WT-17B area, the discharge from the principal aquifer into the effluent channel is estimated to range from 0.5 to 20 gpm per 100 feet of channel length.

Figure 3-8 shows simulated principal-aquifer groundwater elevations in the WT area. As this figure shows, principal-aquifer groundwater pumping at the GE facility exerts a relatively broad influence on groundwater flow patterns in the northern part of the WT investigation area. The area of depressed groundwater elevations induced from pumping wells extends across much of the northeastern property boundary, capturing principal-aquifer groundwater across the downgradient perimeter of most of the active GE facility. Figure 3-9 shows projected flow pathlines and travel times. In conformance with the measured flow pattern shown in Figure 3-7, these figures show principal-aquifer groundwater flowing from the WT Facility to the north-northwest toward the effluent channel. The model indicates a travel time of approximately 4 to 5 years for groundwater to flow from the north edge of the WT Facility to the leading edge of the nitrate plume, which is consistent with the estimate presented in Section 3.2.3.3 calculated using Darcy's law. Once crossing the effluent channel, the groundwater is influenced by the capture zone of site pumping wells and flows to the northeast toward these wells. The termination of the flow pathlines shown in Figure 3-9 at pumping wells WW-13 and WW-14 is not intended to suggest that these wells alone are responsible for the area of depressed groundwater elevations. The area of depression is a result of the combined influence of all the pumping wells at the site, which together produce a time-weighted average of approximately 520 gpm from the principal aquifer. It is important to note that, within the WT investigation area, there are relatively few groundwater-elevation measurement points in the area of depression north of the effluent channel. Considering that groundwater flow patterns in this area are relatively sensitive to influences from the pumping wells, the effluent channel, and surrounding groundwater flow, there is some uncertainty associated with the model predictions in that portion of the WT investigation area.

4.0 Water-Quality Assessment

As discussed in Section 2.0, several surface-water and groundwater monitoring events were conducted during the recent area investigation, and a subsequent routine monitoring program has been implemented. Samples were analyzed for nitrate, ammonia, uranium, and fluoride. These monitoring activities, summarized in Table 2-1, include collection and analysis of:

- surface-water samples from drainage ditches and the effluent channel,
- surficial-aquifer groundwater samples from piezometers and monitoring wells,
- principal-aquifer groundwater samples from monitoring wells, and
- in-situ principal-aquifer groundwater samples from Geoprobe borings.

Tables 4-1 through 4-4 present the analytical results generated for each of the four types of samples listed above, respectively. In-situ groundwater samples from borings and some preliminary monitoring-well samples were analyzed by GE's onsite Chemet Laboratory. The remainder of the samples were analyzed by Oxford Laboratory of Wilmington, North Carolina, for nitrate (Standard Method [SM] 4500-NO_3-F), ammonia (SM 4500-NH_3-E), and fluoride (SM 4500-F^--C) (APHA, et al., 1992), and by RTI's Center for Environmental Measurements and Quality Assurance (CEMQA) Laboratory in Research Triangle Park, North Carolina, for total uranium (EPA Method 200.8) (EPA, 1994). The RTI CEMQA Laboratory also quantified the individual uranium isotopes ^{234}U, ^{235}U, and ^{238}U in those samples found to have total uranium concentrations above 0.002 milligrams per liter (mg/L). Quantification of uranium isotopes is necessary to characterize natural versus anthropogenic uranium.

The findings of this study reveal a groundwater contaminant plume in the principal aquifer consisting of elevated concentrations of nitrate and ammonia. Leakage from one or both of the two north basins holding the nitrate liquid is the suspected source of the contamination. Section 1.2 presented the chemical characterization of the nitrate liquid, and the chemicals of concern with respect to potential environmental contamination from this liquid are nitrate, ammonia, and uranium exhibiting non-natural isotopic ratios. As discussed in Section 1.1, the discovered principal-aquifer contamination apparently is unrelated to the CaF_2 stored in the two south basins or the current CaF_2-removal operation.

Sections 4.1, 4.2, and 4.3, below, provide further discussions of the quality of surface water, surficial-aquifer groundwater, and principal-aquifer groundwater, respectively. Section 4.4 discusses the quality assurance (QA) and quality control (QC) procedures and evaluations associated with the sampling events and analytical results.

4.1 Surface-Water Quality

Table 4-1 presents the analytical results of surface-water samples collected at five sampling locations during four sampling events. These sampling locations are shown in Figure 1-2. Two of the sampling locations are within the effluent channel (SGS-2 is downstream and SGS-3 is upstream of the WT Facility). The other three sampling locations are within the drainage ditches surrounding the WT Facility (SGS-1 is north [downstream], SGS-5 is east, and SGS-6 is west of the WT Facility). As further discussed below, the analytical results suggest that the suspected nitrate basin leakage has not had an observable adverse impact on surface-water quality.

Nitrate concentrations were very low to non-detectable in the samples collected at the two effluent-channel sampling locations and at the drainage-ditch sampling location east of the WT Facility. Although somewhat higher concentrations were measured in a few of the samples collected at the drainage-ditch sampling locations north (downstream) and west of the WT Facility, each of the measured surface-water nitrate concentrations were below the North Carolina surface-water standard of 10.0 mg/L as nitrogen (N) (NCAC T15A 02B .0211).

Ammonia analytical results mostly mimic the nitrate pattens with very low to non-detectable levels in the samples collected at the two effluent-channel sampling locations and at the drainage-ditch sampling location east of the WT Facility, and somewhat higher concentrations measured in a few of the samples collected at the drainage-ditch sampling locations north (downstream) and west of the WT Facility. A North Carolina surface-water standard does not exist for ammonia.

Concentrations of uranium were measured to be greater in the effluent channel than in the drainage ditches surrounding the WT Facility. Concentrations of uranium in the drainage ditches were mostly consistent with background groundwater concentrations. Only one sample collected from the drainage ditches (July 1999 sample from SGS-5) had a uranium concentration above the 0.002 mg/L threshold for analyzing for individual uranium isotopes, and ^{234}U and ^{235}U were not detected in that sample. This result indicates that the nitrate liquid and the CaF_2 material are not the source of the uranium in that drainage-ditch surface-water sample. Although slightly elevated uranium concentrations were detected in the effluent-channel surface-water samples, effluent-channel water quality is routinely monitored by GE, and the detected uranium levels are within regulatory limitations.

Trace levels of fluoride were detected in each of the collected surface-water samples. Each of the measured surface-water fluoride concentrations were below the North Carolina surface-water standard of 1.8 mg/L (NCAC T15A 02B .0211).

4.2 Surficial-Aquifer Groundwater Quality

Table 4-2 presents the analytical results of surficial-aquifer groundwater samples collected from monitoring wells and piezometers. Figures 4-1, 4-2, and 4-3 present the maximum concentrations detected between January 26 and October 28, 1999, of nitrate, ammonia, and uranium, respectively.

With few exceptions, Table 4-2 and Figures 4-1, 4-2, and 4-3 confirm historical observations that, within the WT investigation area, only a small area south of the CaF_2 basins defined by wells WT-1 and the "ditch well" (situated approximately 225 feet east of WT-1) indicates elevated levels of contamination (fluoride, nitrate, uranium, and ammonia) in the surficial aquifer. This contamination has been previously reported to the DENR and, since approximately 1988, GE has periodically pumped groundwater from well WT-1 to recover and treat the contamination.

Well WT-1 and the ditch well are the only surficial-aquifer monitoring locations with concentrations of fluoride and nitrate (Figure 4-1) exceeding their respective North Carolina groundwater standard of 2.0 mg/L and 10.0 mg/L (as N) (NCAC T15A 02L .0202). In addition to these two wells, somewhat elevated levels of ammonia (Figure 4-2) were detected just north of the nitrate basins in wells WT-6 and WTP-10 (7.07 and 10.3 mg/L). In addition to samples collected from WT-1 and the ditch well, the sample collected during one of three sampling events from monitoring well WT-10A had uranium concentration (Figure 4-3) above the 0.002 mg/L threshold for measuring individual uranium isotopes.

Uranium isotopes ^{234}U and ^{235}U were not detected in the sample from well WT-10A indicating that the uranium is naturally occurring and is not related to either of the materials stored at the WT Facility.

Based on site history and the results of the recent investigations, the limited contamination detected in the surficial aquifer south of the CaF_2 basins is believed to be a result of historical surface releases south of the CaF_2 basins and is not related to the materials currently stored at the WT Facility, the current CaF_2-removal operation, or the nitrate and ammonia contamination detected in the principal aquifer.

4.3 Principal-Aquifer Groundwater Quality

Tables 4-3 and 4-4 present the analytical results of principal-aquifer groundwater samples collected from monitoring wells and Geoprobe borings (in-situ groundwater samples), respectively. Figures 4-4/4-5, 4-6, and 4-7 present the maximum concentrations detected between January 26 and October 28, 1999, of nitrate, ammonia, and uranium, respectively.

Figure 4-4 presents a contour line indicating the approximate extent of principal-aquifer groundwater nitrate concentrations exceeding the North Carolina groundwater standard of 10.0 mg/L (as N). The approximate distance of this groundwater nitrate concentration from the north edge of the east nitrate basin is 850 feet. Figure 4-5 presents two three-dimensional renderings of the nitrate plume and the geologic model generated using linear kriging procedures. This figure illustrates that the nitrate plume is restricted to the upper portion of the principal aquifer.

As shown in Figure 4-6, elevated levels of ammonia in principal-aquifer groundwater mostly mimic the nitrate pattern. However, ammonia has been detected deeper (8.3 mg/L in well WT-7C) and farther downgradient (8.5 mg/L in boring WTB-32) than has nitrate.

Figure 4-7 shows the distribution of uranium in principal-aquifer groundwater. Slightly elevated concentrations of total uranium have been detected in some principal-aquifer wells north of the WT Facility. However, several of these samples were further analyzed for the individual uranium isotopes (see Table 4-3). Each of these follow-up analyses revealed natural isotopic ratios, which indicates that the materials stored at the WT Facility are not the source of the uranium. As these wells have been installed fairly recently, even though they have been developed they still may be producing groundwater with low levels of suspended aquifer silt and clay. The suspended silts and clays would elevate the total uranium concentration measured in the groundwater samples due to the natural uranium component of aquifer minerals.

Although trace levels of fluoride have been detected in the area, none of the concentrations are above the 2.0 mg/L North Carolina groundwater standard.

4.4 Quality Assurance/Quality Control Procedures and Evaluations

Appendices A and B are a FSP and a QAPP prepared for the recently implemented WT area routine monitoring program. The February, July, August, and October 1999 sampling events were conducted in general accordance with the procedures described in these plans. These plans, further discussed in Section 7.0, present specifications and methods that are employed to help establish technical accuracy and precision, statistical validity, and documentary evidence of generated data. For example, QA/QC measures described in the plans include collection and analysis of several types of QC samples and prescribed sample handling, storage, custody, and documentation procedures.

The QAPP requires that the laboratory analytical reports generated for this program be evaluated through the process of data validation. Data validation is the procedure of reviewing data against a known set of criteria to verify data validity prior to use. The *EPA Contract Laboratory Program National Functional Guidelines for Inorganic Data Review* (EPA, 1994a) provide general data-validation guidelines that can be applied to the data. RTI has employed these guidelines to develop a data-validation SOP designed to identify biases inherent to the data including assessment of laboratory performance, overall precision and accuracy, representativeness, and completeness. Upon receipt of laboratory analytical reports, the data are validated using the SOP by reviewing the following information/analytical results:

- Data completeness,
- Holding-time compliance,
- Field and laboratory blank analyses,
- Field duplicate analyses,
- Laboratory control sample analyses,
- Matrix spike analyses,

- Laboratory duplicate analyses, and
- Performance evaluation sample analyses.

The QAPP includes quantitative QC acceptance criteria, and data-validation qualifiers (flags) are applied to those sample results which fall outside of specified tolerance limits, and, therefore, do not meet the program's QA objectives. Data validation memoranda prepared for each sampling event include a tabulation of flagged analytical results; present QA/QC issues, findings, and deficiencies, if any; and address whether the quality of the data is appropriate for its intended use. Appendix G presents five data validation memoranda prepared for the WT area investigation sampling events conducted to date. Overall, the data were found to be complete, of good quality, and useable for their intended purpose. In accordance with the data validation SOP, no results were rejected but a few analytical results required minor qualification.

5.0 Contaminant Fate and Transport

This section considers the properties of the three chemicals of concern in the nitrate liquid: nitrate, ammonia, and uranium. This discussion is focused on those properties that might affect the disposition of these constituents as they infiltrate toward and/or migrate within the principal aquifer. Also presented are discussions of the field and laboratory measurements and the numerical modeling performed during the WT area investigation to evaluate and predict the fate and transport of these substances. A discussion of potential receptors of the discovered contamination that considers the results of the fate and transport analyses also is presented.

5.1 Chemical Properties

This section presents discussions of the chemical properties of the three chemicals of concern present in the nitrate liquid: nitrate, ammonia, and uranium.

5.1.1 Aqueous Nitrogen Chemical Reactions. In natural waters, nitrogen may be present as multiple species, including ammonium (NH_4^+), ammonia (NH_3), nitrite (NO_2^-), nitrate (NO_3^-), dissolved nitrogen gas (N_2), and nitrous oxide (N_2O). The prevalence of different nitrogen species depends on the groundwater geochemistry and a series of aqueous chemical and biochemical reactions. Reactions that are potentially relevant to the groundwater chemistry of nitrogen in the WT area include denitrification, nitrification, and nitrate reduction. Figure 5-1 schematically shows the pathways and end products for these reactions. The descriptions of these three reactions, below, include the reaction mechanisms and the geochemical conditions required for the reactions to take place.

5.1.1.1 Denitrification. Denitrification refers to the process whereby nitrate is reduced to either nitrous oxide and/or nitrogen gas (Korom, 1992). Denitrification is typically microbially-mediated, although it can occur abiotically in some restricted cases. The four general requirements for denitrification are the following: (1) the presence of nitrate and/or other nitrogen oxides as terminal electron acceptors; (2) the presence of bacteria with the metabolic capacity for denitrification; (3) suitable electron donors (organic carbon or suitable reduced inorganic compounds); and (4) anaerobic conditions or restricted oxygen availability (Korom, 1992).

Bacteria in groundwater obtain energy through the oxidation of organic or inorganic compounds, with these compounds acting as the electron donors. If the electron donor is organic, the organism is organotrophic and almost always heterotrophic (uses organic carbon for a cellular carbon source). If the electron donor is inorganic, the organism is lithotrophic and almost always autotrophic (uses carbon dioxide for cellular carbon). In this discussion, heterotrophic denitrification refers to denitrification using an organic carbon energy source, whereas autotrophic denitrification refers to denitrification using an inorganic energy source.

In deriving energy through oxidation of an electron donor, bacteria require an electron receptor. Bacteria will utilize a series of different electron receptors, preferentially using the available electron receptor that will provide the most energy. In aerobic environments (with readily available dissolved oxygen [DO]), oxygen is the preferred electron acceptor, because reactions with oxygen supply the most energy. As the oxygen supply decreases and if nitrate is available, nitrate becomes the next preferred electron acceptor, which drives the process of denitrification. The point at which this transition occurs differs among organisms, but in general, denitrification becomes most prevalent at DO concentrations less than 2 mg/L (Korom, 1992; Gillham and Cherry, 1978). Gillham and Cherry (1978) indicate that the oxidation-reduction potential (ORP) is typically less than 320 millivolts where denitrification readily proceeds.

Heterotrophic denitrification requires a source of organic carbon to serve as the electron donor. Generally, organic carbon concentrations greater than 2 mg/L are necessary for active denitrification, although the reaction can occur at lower concentrations (Wassenaar, 1995; Trudell, 1986). An example heterotrophic denitrification reaction is provided below:

$$5C + 4NO_3^- + 2H_2O \rightarrow 2N_2 + 4HCO_3^- + CO_2$$

where *C* represents an arbitrary organic compound (Korom, 1992). As this reaction indicates, denitrification produces dissolved inorganic carbon. In active-denitrification areas in some groundwater systems with low buffering capacity, the dissolved carbon dioxide (CO_2) forms carbonic acid which can slightly lower the groundwater pH.

As described above, autotrophic denitrification requires a reduced inorganic compound to serve as the electron donor. Examples of suitable inorganic compounds include reduced manganese (Mn^{+2}), ferrous iron (Fe^{+2}), and sulfides such as bisulfide (HS^-) or pyrite (FeS_2). One example autotrophic denitrification reaction involving ferrous iron is provided below (Korom, 1992):

$$2HNO_2 + 6Fe^{2+} + 6H^+ \rightarrow N_2 + 6Fe^{3+} + 4H_2O$$

In this reaction, a form of nitrite (HNO_2) is an intermediate in the overall denitrification conversion between NO_3^- and N_2. It is noteworthy that the conversion of NO_3^- to HNO_2 by ferrous iron can occur abiotically (Korom, 1992). Another abiotic denitrification example involves pyrite functioning as the electron donor (Aravena and Robertson, 1998).

A variety of rates have been reported for field-scale denitrification in groundwater systems. The rate will depend on geochemical conditions (e.g., ORP, DO), nitrate availability, and the availability of suitable electron donors (organic carbon or reduced inorganics). Reported half lives have ranged from one month to two years (Korom, 1992; Böttcher et al., 1990; Aravena and Robertson, 1998).

In aquifers, observed decreases in nitrate concentration in both the direction of groundwater flow and with depth have often been attributed to denitrification (e.g. Mariotti et al., 1988; Trudell et al., 1986). Therefore, given suitable system conditions, including low DO concentrations, the presence of denitrifying bacteria, and a suitable electron donor (organic carbon or reduced inorganic compounds), nitrate may be effectively removed from groundwater systems through denitrification.

5.1.1.2 Nitrification and Nitrate Reduction. Nitrification is the oxidation of ammonium to nitrate. Nitrification requires plentiful supplies of DO. Nitrification normally occurs above the water table in the unsaturated zone where oxygen is abundant (Wassenaar, 1995). However, given sufficient quantities of oxygen, nitrification may also occur in the saturated zone.

When ORP decreases and oxygen supplies are limited, the reverse of nitrification, nitrate reduction, may occur, whereby nitrate is reduced to ammonium. Nitrite is an intermediate compound in both nitrification and nitrate reduction.

As opposed to denitrification, which results in a net loss of nitrogen from the system, both nitrification and nitrate reduction conserve nitrogen in the system (Korom, 1992). Because both nitrate reduction and denitrification occur under similar system conditions, both processes can occur simultaneously. Some studies have suggested that nitrate reduction can compete with denitrification under some conditions (Korom, 1992). However, denitrification is the dominant reaction and accounts for the majority of nitrate loss in most environmental conditions (Smith, 1991; Hunter, 1999).

5.1.2 Nitrate Properties. Nitrate is the form of nitrogen most commonly found in natural groundwater systems. Ambient concentrations of nitrate in groundwater in the United States are approximately 3 mg/L, and concentrations in excess of 3 mg/L are generally considered to represent anthropogenic inputs (U.S. EPA, 1995).

Nitrate is highly soluble in water and can be persistent over a wide range of environmental conditions. Because nitrate is anionic, it does not characteristically sorb to aquifer solids. The high solubility and low sorption potential allow nitrate to migrate along groundwater pathways with little or no retardation (Freeze and Cherry, 1979). In practice, the only effective way for nitrate to be removed from groundwater systems is by reduction, typically through denitrification, as described in Section 5.1.1.1 (Postma et al., 1991).

5.1.3 Ammonia Properties. Although nitrate is the predominant nitrogen species present in natural groundwater systems under most environmental conditions, ammonium (NH_4^+) and ammonia (NH_3) may also be present. Generally, these latter two species exist in equilibrium with each other. This equilibrium is strongly influenced by pH; at pH values less than 9.2, most of the ammonia nitrogen is present as ammonium.

Because ammonium is a positively charged ion (a cation), it is subject to cation exchange and sorption to aquifer solids. Many natural aquifers contain negatively-charged surfaces, which attract and sorb cations such as ammonium. These sorption reactions can significantly slow down (retard) the migration of cations in groundwater, effectively immobilizing the constituents in some cases.

The degree of retardation is dependent upon the surface charge of the substrate and the physical and chemical characteristics (size, charge) of the constituent. Ammonium is relatively large compared to some competing constituents, and it contains only a +1 charge. These two factors combine to make ammonium somewhat less competitive for sorption sites than some other cations. However, measured ammonium distribution coefficients in some natural sandstone aquifers ranged from 2 to 10 liters per kilogram (L/kg) (Drever, 1988). These values translate to a range of approximately 16 to 80 for the retardation factor, which indicates that the ammonium will migrate between 16 and 80 times slower than groundwater in these systems. Collectively, this information indicates that ammonium transport will typically be somewhat limited by sorption in groundwater systems.

In summary, ammonia in environmental systems is likely to be present as the cationic ammonium ion. In addition, although ammonium is soluble in groundwater, its migration is likely to be somewhat limited by sorption processes.

5.1.4 Uranium. Natural uranium is ubiquitous in the environment and is comprised predominantly of the isotope ^{238}U. The natural abundances of ^{238}U, ^{235}U, and ^{234}U are 99.275, 0.720, and 0.005 percent, respectively. However, low-enriched uranium used for nuclear fuel has higher percentages of ^{235}U and ^{234}U. Percent enrichment of an environmental sample is calculated by dividing the concentration of the isotope of interest by the concentration of total uranium and multiplying the result by 100. The percent enrichment of ^{234}U and ^{235}U in the CaF_2 and nitrate liquid are approximately 2.2 to 2.5 percent by weight. The presence of uranium at enriched levels (above the naturally-occurring abundance of 0.7 percent ^{235}U) can be used as a reliable indication of contamination originating from the materials stored at the WT Facility.

Uranium occurs in three oxidation states; U^{+4}, U^{+5}, and U^{+6}. In natural waters the U^{+4} (uranous) and U^{+6} (uranyl) oxidation states predominate. The aqueous geochemistry of dissolved uranium is complex and the concentration of uranium in groundwater is controlled by several factors. The importance of the ORP environment, pH, the types and concentrations of other species which complex with uranium, and adsorption is discussed below.

One important control on the behavior of uranium in groundwater is the ORP sensitivity of uranium; that is, the sensitivity of uranium to the amount of oxygen present in groundwater. At low oxygen concentrations and under reducing conditions, U^{+4} and its aqueous complexes predominate, whereas in oxidized groundwater, uranium exists mainly as U^{+6} and its complexes. This ORP sensitivity leads to differences in the concentration of dissolved uranium in groundwater because U^{+6} and its complexes are highly soluble, whereas U^{+4} and its complexes have extremely low solubilities. Thus, low oxygen or reducing groundwater would be predicted to have lower levels of dissolved uranium than oxidizing groundwater.

The pH and the presence of other species that form complexes with uranium are also important controls on the concentration of dissolved uranium in groundwater. In natural water, uranium (U^{+4}) generally forms strong carbonate complexes. The carbonate complexes are particularly important because they increase the solubility of uranium minerals, facilitate oxidation of U^{+4}, and limit the extent of uranium adsorbed in oxidized waters. Other uranium complexes which are important include those formed with hydroxyl, fluoride, phosphate, and sulfate species.

Adsorption is another important control on the concentration of dissolved uranium in groundwater. The ferric ion (Fe^{+3}) oxyhydroxides are generally the most important potential sorbents of uranium because they commonly occur in soils and sediments and they exhibit strong sorptive behavior toward U^{+6} (Langmuir, 1997). Organic matter is second in importance. The extent to which adsorption of U^{+6} occurs in groundwater depends on the aqueous speciation of uranium, which in turn is a function of the ORP conditions, pH, and presence of other species.

The concentration of dissolved uranium in a particular groundwater environment will depend predominantly on the chemical composition of the groundwater and the complex interplay of the geochemical parameters described above which are present in that environment.

5.2 Evaluation of Contaminant Attenuation

As described in Section 5.1, nitrogen compounds like nitrate and ammonia can undergo a series of reactions, including denitrification, nitrification, nitrate reduction, and sorption. Each of these processes is potentially relevant to the fate of these groundwater constituents. This section describes a series of analyses designed to evaluate the feasibility that these various reactions are occurring and to assess their importance on the potential attenuation and mobility of nitrate and ammonia in the WT-area principal-aquifer groundwater system. In addition, this section includes the results of a predictive transport model of the nitrate plume.

The following discussion does not include an evaluation of the attenuation and mobility of uranium in the WT-area principal-aquifer groundwater system. Uranium with non-natural isotopic ratios has not been detected in the principal aquifer downgradient from the WT Facility. Therefore, the uranium component of the released nitrate liquid apparently has been effectively attenuated by the geologic materials situated between the basins and the principal aquifer through the geochemical processes discussed in Section 5.1.4.

5.2.1 Geochemical Parameters. A series of parameters were analyzed to evaluate the geochemical characteristics of WT area groundwater and the potential for various transformation reactions to occur. The analyzed parameters included DO, ORP, pH, and total organic carbon (TOC). Table 5-1 provides the results of these analyses and summary statistics for selected parameters measured in the groundwater samples. Some parameters were measured in surface water and surficial-aquifer groundwater for comparison, however the discussion here is focused on the principal-aquifer results. Figure 5-2 shows the distribution of DO, ORP, and TOC in the principal aquifer in the WT area.

In discussing the geochemistry of aquifers, it is important to understand that local, micro-scale conditions can be highly variable within porous media. Geochemical parameters can vary dramatically across distances as small as inches or feet in many systems. Therefore, bulk groundwater samples (e.g. from monitoring wells screened across several feet of aquifer) may only represent average conditions within a highly variable sample zone. For example, bulk samples may not accurately reflect local microsites where biodegradation is most active. Therefore, geochemical parameters should be interpreted carefully with reference to processes like biodegradation, which require particular geochemical conditions.

The average pH of 5.18 (see Table 5-1) in the principal aquifer is relatively low. Although rates of biological activity typically decrease as water becomes more acidic, the pH of the principal aquifer is within the potential range for active biodegradation (Wetzel, 1983). Moderate decreases in pH can actually be indicative of biological activity due to the production of carbon dioxide and its dissolution in groundwater to form carbonic acid. The pH is relatively low in all of the principal-aquifer measurements (except in WW-14 and WT-7C, which are both screened deeper within the aquifer than the other WT area principal-aquifer monitoring wells with pH measurements). This relatively low pH may indicate moderate biological activity throughout the area of measurement. Alternatively, the principal aquifer groundwater may have a relatively low pH due to a different, unknown geochemical interaction. The lowering of the pH does indicate that the upper principal-aquifer system is not strongly buffered and likely does not contain an abundance of carbonate material.

The DO average of 2.75 mg/L in the principal aquifer is moderately low. Water fully saturated with oxygen at the measured groundwater temperature (between 16 and 17°C) would have a DO content between 9 and 10 mg/L (Wetzel, 1983). Therefore, DO is somewhat depleted in the principal aquifer. Although the DO is low, it is slightly above the range considered ideal for denitrification (Gillham and Cherry, 1978). Nevertheless, denitrification can occur under a wide range of DO conditions, including the levels measured in the WT area (Gillham and Cherry, 1978). The DO in the upgradient wells CW-2B and CW-3B is significantly higher (6.54 and 7.07 mg/L, respectively) than in the other locations. Therefore, lower DO levels predominate in the general vicinity of the nitrate plume. This pattern may indicate increased biological activity in this area, which will deplete DO levels.

The ORP is moderately low in the principal aquifer, with an average of 143 mV. Because ORP is sensitive to pH, it is customary to express ORP as the equivalent potential at a pH of 7 (Wetzel, 1983). The ORP can be adjusted for acid conditions by subtracting 58 mV for every pH unit lower than 7. The corrected average ORP for the principal aquifer would thus be 37 mV using the average pH of 5.2 and the measured potential of 143 mV. This range for ORP is appropriate for denitrification (Gillham and Cherry, 1978). Nitrate reduction may also occur under these conditions, although it is typically less significant than denitrification (Snoeyink and Jenkins, 1980; Smith et al., 1991).

The TOC in the principal aquifer is relatively low, with an average of 1.59 mg/L. This level of TOC is sufficient to act as a substrate for heterotrophic denitrification (Trudell et al., 1986). However, because the TOC levels are relatively low, TOC would likely be a limiting factor in this denitrification process. Therefore, amendment of the aquifer with a source of soluble organic carbon may significantly stimulate the rates of denitrification. It is important to note that denitrification can also occur via an autotrophic process not relying on organic carbon. In the autotrophic pathway, reduced inorganic species such as ferrous iron (Fe^{+2}), reduced manganese (Mn^{+2}), bisulfide (HS^-), and pyrite (FeS_2) can serve as electron donors driving the denitrification, while nitrate serves as the electron receptor (Korom, 1992).

5.2.2 Isotope Geochemistry. During denitrification, the break of chemical bonds between nitrogen and oxygen leads to a fractionation of nitrogen and oxygen isotopes (Clark and Fritz, 1997). Through this fractionation process, the remaining nitrate becomes isotopically heavy with respect to nitrogen and oxygen with $^{15}N/^{14}N$ and $^{18}O/^{16}O$ ratios increasing as denitrification proceeds. As an additional measure of the potential for denitrification in the principal aquifer, isotopic ratios were measured for nitrogen and oxygen in wells upgradient and along the centerline of the nitrate plume.

The isotopic enrichment data are expressed using the delta (δ) convention and permil ($^{o}/_{oo}$) units. This fractionation expression is calculated by the following method ($\delta^{15}N$ is calculated below as an example, but the calculation of $\delta^{18}O$ is similar):

$$\delta^{15}N\ (^{o}/_{oo}) = [(R_{sample}/R_{standard})-1] \times 1000$$

where R = (mass of ^{15}N) /(mass of ^{14}N).

Table 5-1 and Figure 5-3 present the results of the isotopic enrichment analyses. Figure 5-4 plots the $\delta^{15}N$ versus the $\delta^{18}O$ data. These figures indicate a clear increasing trend in the isotopic enrichment of oxygen and nitrogen between the upgradient and the downgradient locations. The nitrogen enrichment continues to increase as the downgradient distance from the source increases, however the oxygen enrichment between these downgradient locations remains fairly stable.

The general increase in the isotopic ratios between the upgradient and downgradient locations (around 7 $^{o}/_{oo}$ increase for ^{18}O and around 6 $^{o}/_{oo}$ increase for ^{15}N) is suggestive that denitrification may be occurring in the groundwater system. However, more significant enrichments (greater than 60 $^{o}/_{oo}$ and 20 $^{o}/_{oo}$ for ^{18}O and ^{15}N, respectively) have been reported in many studies (Böttcher et al., 1990; Mariotti et al., 1988). Mariotti (1988) reports that faster denitrification rates actually lead to less isotopic fractionation of the nitrate than slower denitrification rates. This trend is due to the fact that denitrification shows less preference for particular isotopes as the rate of denitrification increases. It is therefore possible that the limited increase in the isotopic ratios observed in Figure 5-4 is due to a faster denitrification rate. However, it is also possible that the pattern in the data is due to limited denitrification at a smaller rate. Based on the limited time that the nitrate plume has been monitored, there is insufficient data to determine which of these scenarios is accurate.

In summary, the isotopic enrichment data indicate that denitrification is likely occurring, however the rate of denitrification is as yet unknown. As monitoring of the plume continues, further analyses will indicate the degree of denitrification in the system.

5.2.3 Predictive Modeling of Nitrate Migration. A numerical transport model was developed to enhance the understanding of the nitrate plume and to allow predictions of plume behavior into the future. Appendix F documents the development and results of the transport model in detail. This section provides a general discussion of the model and the modeling predictions.

The uncertainty about the timing and the characteristics of the release of contamination from the source area makes the modeling of contaminant transport in the WT area principal aquifer inherently uncertain. It is unknown when and how much nitrate liquid reached the principal aquifer, nor the contaminant concentrations that resulted after the released material passed through the surficial aquifer and the semiconfining layer. In addition, it is unknown how much nitrate is being transformed into other compounds by processes described in Section 5.1. Given these uncertainties, the predictive transport simulations were designed to bracket the potential future behavior of the plume with two modeling scenarios -- a degradation scenario minimizing the potential future migration, and a highly conservative no-degradation scenario maximizing the potential future migration. The degradation scenario includes a reasonable rate of nitrate degradation. The no-degradation scenario does not include any nitrate degradation.

Initially, a series of calibration and sensitivity-analysis simulations were performed to estimate reasonable ranges for the input parameters and to ensure model reliability. Appendix F describes these efforts in detail. The calibration of the nitrate transport model involved varying the degradation rate until a simulated, stable plume provided a good match to the measured plume. Results of this calibration effort are shown in Figure 5-5. As this figure indicates, the simulated plume matches the measured values quite well. The only measurements falling outside the simulated concentration ranges indicated in the figure are from borings WTB-33, WTB-29, and WTB-30. In each case, the concentration in an adjacent monitoring well (WT-7B, WT-13B, and WT-14B, respectively) does match the simulated results. Therefore, there is some discrepancy between laboratory analytical results for in-situ groundwater samples taken from certain borings at specific aquifer horizons and for nearby monitoring-well samples taken from a larger screened interval within the aquifer. However, the model closely matches the maximum concentrations measured at the monitoring wells.

As mentioned above, it was assumed during the transport model calibration that the currently measured plume is stable. A stable plume remains unchanged over time because the contaminant mass entering the aquifer is balanced by the mass being attenuated. However, due to the absence of nitrate monitoring data prior to 1998, it is impossible to determine whether the existing plume is indeed in a stable configuration. Nevertheless, the assumption of a stable plume allows the model to subsequently predict the minimum possible future migration of the plume after the nitrate basin liners were replaced (the degradation model scenario). The maximum potential future migration of the plume was then estimated by eliminating the degradation attenuation mechanism (the no-degradation model scenario). Thus, these simulations together bracket the potential future behavior of the nitrate plume, even given the uncertainties about nitrate degradation mechanisms and the contaminant-release history. It is important to note that even though the calibration model setup minimizes potential future migration, the resulting degradation rate (a half life of 1.12 years) is well within reported field rates for denitrification. Further, considering the accurate match between the simulation and the measured results (Figure 5-5), the estimated degradation rate is a reasonable possibility for the current plume and so was used in the degradation modeling scenario.

Table 5-2 summarizes the transport-parameter values used to model the degradation and the no-degradation scenarios. Because the release from the nitrate basins has been eliminated, there is no continuing source of contamination in either model scenario. The initial concentrations for both scenarios correspond to the calibrated nitrate plume that matches currently measured conditions (the plume shown in Figure 5-5). The migration of the plume from these initial concentrations is then predicted into the future using the transport scenarios described in Table 5-2. Sorption is not included in either scenario, because nitrate is a non-sorbing anion. The dispersivity estimate is relatively low and is based on the scale of the plume and model calibration, as described in Appendix F. It is important to note that the model is relatively insensitive to variations in dispersivity values within the low range used for these simulations.

Figures 5-6 and 5-7 show results of the degradation scenario. With these transport assumptions, the nitrate concentration falls below the North Carolina groundwater standard of 10 mg/L (as N) within 5 years. Also, the plume remains within approximately 900 ft of the north edge of the WT Facility throughout this period. In the degradation scenario, the initial plume is assumed to be stable and fed by a continuous source of nitrate entering the principal aquifer. Therefore, once the nitrate source is removed, the plume does not migrate farther downgradient. Rather, the plume maintains a position similar to the initial condition, and experiences decreasing concentrations over time due to natural-attenuation processes.

Figures 5-8 and 5-9 show results of the conservative no-degradation scenario. With these transport assumptions, the nitrate concentration falls below 10 mg/L (as N) within 14 years. The plume does migrate downgradient, however it is fully captured by recovery wells WW-13 and WW-14 (the scenario assumes current pumping conditions are maintained). As described above, the no-degradation scenario assumes no attenuation processes are occurring. The only mechanism that would result in decreasing contamination concentrations is mixing (dispersion) with groundwater that contains no nitrate or low concentrations of nitrate. In areas of converging groundwater flow (e.g., the area of depressed groundwater levels surrounding the GE pumping-well network), mixing can be a particularly effective mechanism for lowering concentrations. This effectiveness results from increased groundwater velocities in these areas and from the fact that groundwater is converging from a broad area into a smaller area, particularly if a significant portion of the groundwater contains little or no contamination. Therefore, even in the absence of degradation (the conservative no-attenuation scenario), decreasing concentrations, due to mixing, limit the time that the nitrate plume will be above 10 mg/L (as N) to less than 14 years.

5.2.4 Nitrate to Ammonia Ratios. Strong evidence for the attenuation of nitrate is found by comparing the measured nitrate and ammonia distribution in the principal aquifer (Figures 4-4 and 4-6). As the concentrations for well WT-7C and boring WTB-32 indicate, the ammonia has migrated notably farther and deeper than has nitrate. Considering that ammonium (see footnote on page 2) adsorbs relatively readily and that nitrate is unreactive with the solid matrix, in the absence of other attenuating mechanisms, the nitrate should migrate farther than the ammonia. In contrast, the nitrate in the WT area has actually migrated less than the ammonia. Therefore, additional attenuating mechanisms like denitrification are likely limiting the nitrate plume extent. Table 5-3 shows calculated ratios of nitrate to ammonia concentrations in wells along the plume transect. As this table indicates, the ratio in the nitrate liquid was measured to be 15.2, and this ratio decreases dramatically from 2.7 to less than 0.03 as the distance downgradient from the source increases. This analysis clearly suggests that the nitrate is attenuating more significantly than ammonia.

5.2.5 Natural Attenuation Assessment Summary. The geochemical, isotopic, and modeling results collectively suggest that natural attenuation of the nitrate plume may be occurring. The most likely attenuation mechanism appears to be denitrification, however some of the geochemical parameters (e.g., DO and TOC) are slightly outside the ideal range for this process. Nevertheless, other evidence (e.g., nitrate to ammonia ratios) clearly indicates that nitrate is attenuating, although specific mechanisms and their effectiveness remain uncertain. The degree to which natural attenuation is limiting the nitrate contamination in the WT area will only be able to be better understood through continued monitoring.

5.3 Potential Receptors

There are no identified potential drinking water receptors to the principal-aquifer groundwater contamination. Considering the fate and transport analysis discussed in the previous section, the only potential receptors of the identified principal-aquifer groundwater contamination would be workers that come in contact with water produced from wells WW-13 and WW-14, should the contamination ever reach those wells. The water produced from these wells is used as plant process water, not as drinking water. If warranted by elevated groundwater contaminant concentrations in these wells, GE would evaluate appropriate water-treatment techniques in consideration of the use and ultimate disposition of the water. There is no other foreseeable opportunity for human contact or consumption of groundwater containing these contaminant levels considering that the contaminant plume is well within the GE property, so installation of new wells tapping this contamination that would be used for other purposes (e.g., domestic wells) is not possible.

There are no identified potential drinking water receptors to the surficial-aquifer groundwater contamination. As discussed in Section 4.2, within the WT investigation area, only the small area south of the CaF_2 basins defined by wells WT-1 and the "ditch well" indicates levels of contamination exceeding regulatory standards. The WT area investigation results indicate that the periodic pumping of well WT-1 may be helping to minimize spreading of this plume from this small area. Groundwater pumped from WT-1 is directly diverted into the WT Facility treatment stream. Because the nitrate liquid treated at the WT Facility contains higher levels of nitrate than the groundwater, no additional potential risk is introduced to workers who may come into contact with the groundwater pumped from well WT-1. There is no other foreseeable opportunity for human contact or consumption of groundwater containing these contaminant levels considering that the affected area is well contained on GE property within the WT investigation area, so installation of new wells tapping this contamination that would be used for other purposes (e.g., domestic wells) is not possible.

As stated in Section 4.1, although low levels of nitrate and ammonia have been detected in the drainage ditches surrounding the WT Facility, concentrations are currently below applicable regulatory levels. Therefore, an evaluation of potential surface-water receptors was not performed.

6.0 Conclusions

Based on the results of the investigation activities described in this document, the following conclusions are drawn:

- Leakage from one or both of the two north basins holding nitrate liquid is the suspected source of the nitrate and ammonia contamination found in principal-aquifer groundwater in the WT area. GE has addressed the suspected leakage by replacing the liners in both of the nitrate basins and by removing in-ground piping and a sump previously situated between these basins.

- Uranium detected in principal-aquifer groundwater north of the WT Facility demonstrates natural isotopic ratios. Therefore, these uranium detections are unrelated to the materials stored at the WT Facility. Due to the chemical composition of the groundwater and the complex interplay of the geochemical parameters described Section 5.1.4, the uranium component of the released nitrate liquid apparently has been effectively attenuated by the geologic materials situated between the basins and the principal aquifer.

- The field and laboratory measurements and contaminant transport modeling suggest that the nitrate identified in the principal aquifer may be undergoing natural attenuation by denitrification, but the specific processes and degree to which they are lowering groundwater contaminant concentrations are not fully defined. The ammonia identified in the principal aquifer is understood to be attenuated by sorption to the aquifer substrate. The observation that the ammonia plume has migrated farther and deeper than the nitrated plume further suggests that natural attenuation of the nitrate contamination is occurring.

- Contaminant transport modeling predicts that, if no natural-attenuation processes were occurring, the ammonia and nitrate plumes would be contained by GE's active pumping-well network north of the effluent channel and recovered by wells WW-13 and WW-14. In this highly conservative scenario, concentrations of nitrate exceeding the North Carolina groundwater standard of 10 mg/L (as N) are predicted to reach well WW-14 within 5 years from present, and the maximum nitrate concentration in groundwater would be below this regulatory level within approximately 14 years.

- Given a degree of natural attenuation that is reasonable for this geochemical system, fate and transport modeling predicts that the position of the nitrate contamination plume would be stable and would degrade in place. In this scenario, groundwater nitrate concentrations exceeding the North Carolina groundwater standard of 10 mg/L (as N) are not predicted to reach well WW-14, and the maximum nitrate concentration in groundwater would degrade to below this regulatory level within approximately 5 years.

- Although low levels of nitrate and ammonia have been detected in the drainage ditches surrounding the WT Facility, concentrations are currently below applicable regulatory levels.

- The contamination of the surficial aquifer in the small area in the vicinity of well WT-1 and the ditch well is attributed to historical surface releases, has been reported previously to the DENR by GE, and is not attributed to the nitrate basin leakage.

7.0 Recommendations

Considering the conclusions presented in Section 6.0, the following recommendations are presented:

- ***Continue the Routine Monitoring Program.*** Consistent with EPA's directive on monitored natural attenuation (EPA, 1997), continuation of the recently initiated routine surface-water and groundwater monitoring program is intended to accomplish the following:
    - Demonstrate that natural attenuation is occurring;
    - Identify toxic transformation products, if applicable;
    - Evaluate whether the plume is expanding in size;
    - Detect new releases of contaminants that could impact the groundwater system being monitored;
    - Demonstrate efficacy of institutional controls, if applicable;
    - Detect changes in environmental conditions that may reduce the efficacy of the natural-attenuation processes; and
    - Evaluate when North Carolina groundwater standards have been met.

Specifically, continuing the recently initiated routine surface-water and groundwater monitoring program enables GE and RTI to:

- Verify numerical flow-model predictions that principal-aquifer groundwater flow paths from the north WT basins terminate at wells WW-13 and WW-14 and that the only potential receptors of the identified principal-aquifer groundwater contamination would be workers that come in contact with the Facility production water (not used as drinking water) pumped from these wells, should the contamination ever reach that far;

- Update the contaminant transport modeling predictions of future plume configurations by incorporating a more accurate understanding of the degree to which natural-attenuation processes are occurring;

  - ➢ Monitor for any potential breakthrough of anthropogenic uranium from the nitrate liquid, which is currently observed to be effectively attenuated by the geologic materials situated between the basins and the principal aquifer; and
  - ➢ Identify if an evaluation of additional remedial measures, such as in-situ enhancement of biological denitrification (e.g., soluble or insoluble carbon source injection), is warranted.

- ▸ ***Enhance the Existing Monitoring Network.*** Due to remaining uncertainties, enhancements to the existing monitoring network are recommended. The planned locations for these new wells are shown in Figure 7-1, and these new wells will be included in the routine monitoring program.
  - ➢ Construction of two new surficial-aquifer monitoring wells, WT-18A and WT-19A, is currently being completed at the northwest and northeast corners of the WT Facility in order to better understand where nitrate liquid had leaked from the WT Facility downward through the surficial aquifer and semiconfining layer.
  - ➢ There is still some uncertainty associated with the model predictions north of the effluent channel, and one new principal-aquifer monitoring well, WT-20B, is recommended in an area sparsely monitored to help resolve the uncertainty. This well would be installed in the area that is inferred to be the western extent of the area hydraulically influenced by GE's pumping-well network because accurately predicting groundwater flow directions and contaminant migration paths in that portion of the WT investigation area is relatively sensitive to influences from the pumping wells, the effluent channel, and surrounding groundwater flow patterns.
  - ➢ Two new principal-aquifer monitoring wells, WT-21B and WT-22B, are recommended to be installed in the area south of well WW-14 where the fate and transport model predicts the contaminant plume would migrate in event that natural-attenuation processes have not stabilized the plume position.

- ***Prepare Annual Reports.*** It is recommended that GE submit annual reports to the DENR Groundwater Section. The reports will present the results of the routine monitoring events, any changes to the interpretations and predictions presented in this report, and any recommendations for monitoring-program modifications or for an evaluation of additional remedial measures.

Figure 7-1 shows the monitoring wells and surface-water sampling locations recommended for routine monitoring, including the planned new wells discussed above. Appendices A and B are a FSP and a QAPP prepared for the routine monitoring program. The FSP reiterates the objectives of the sampling program and provides specific information on sampling locations, field methods and sampling procedures, sample handling and custody, QC sampling, and field documentation. Standard operating procedures are included and referenced where appropriate. The QAPP designates and documents the specifications and methods that will be employed to help establish technical accuracy and precision, statistical validity, and documentary evidence of generated data. The QAPP is the quality-controlling document for activities relating to the collection and analysis of samples which are described in the project FSP and is used in conjunction with the FSP. The QAPP helps ensure that the data obtained for this project are of sufficient quality to meet the project-specific objectives. The QAPP contains general and specific information regarding field sampling, laboratory, and analytical procedures. Field and laboratory personnel are provided with instructions regarding activities to be performed before, during, and after field investigations. The QA/QC protocols included in this QAPP are adopted by reference in the FSP. The QAPP was prepared in general accordance with EPA guidelines described in *EPA Guidance for Quality Assurance Project Plans, EPA QA/G-5* (EPA, 1998).

Currently, groundwater and surface-water samples are collected quarterly for analysis of nitrate, ammonia, and uranium. Groundwater samples also will be analyzed at least annually for natural-attenuation indicator parameters such as TOC, ORP, and DO. Depending on the findings of the sampling and analysis activities, natural-attenuation monitoring parameters may be added or deleted from the list, and the sampling schedule may be modified. In addition, at least one additional set of analyses will be performed to evaluate nitrogen and oxygen isotopic ratios and to measure other parameters such as ferrous iron and manganese, which might indicate which natural-attenuation reactions are occurring.

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FIGURES

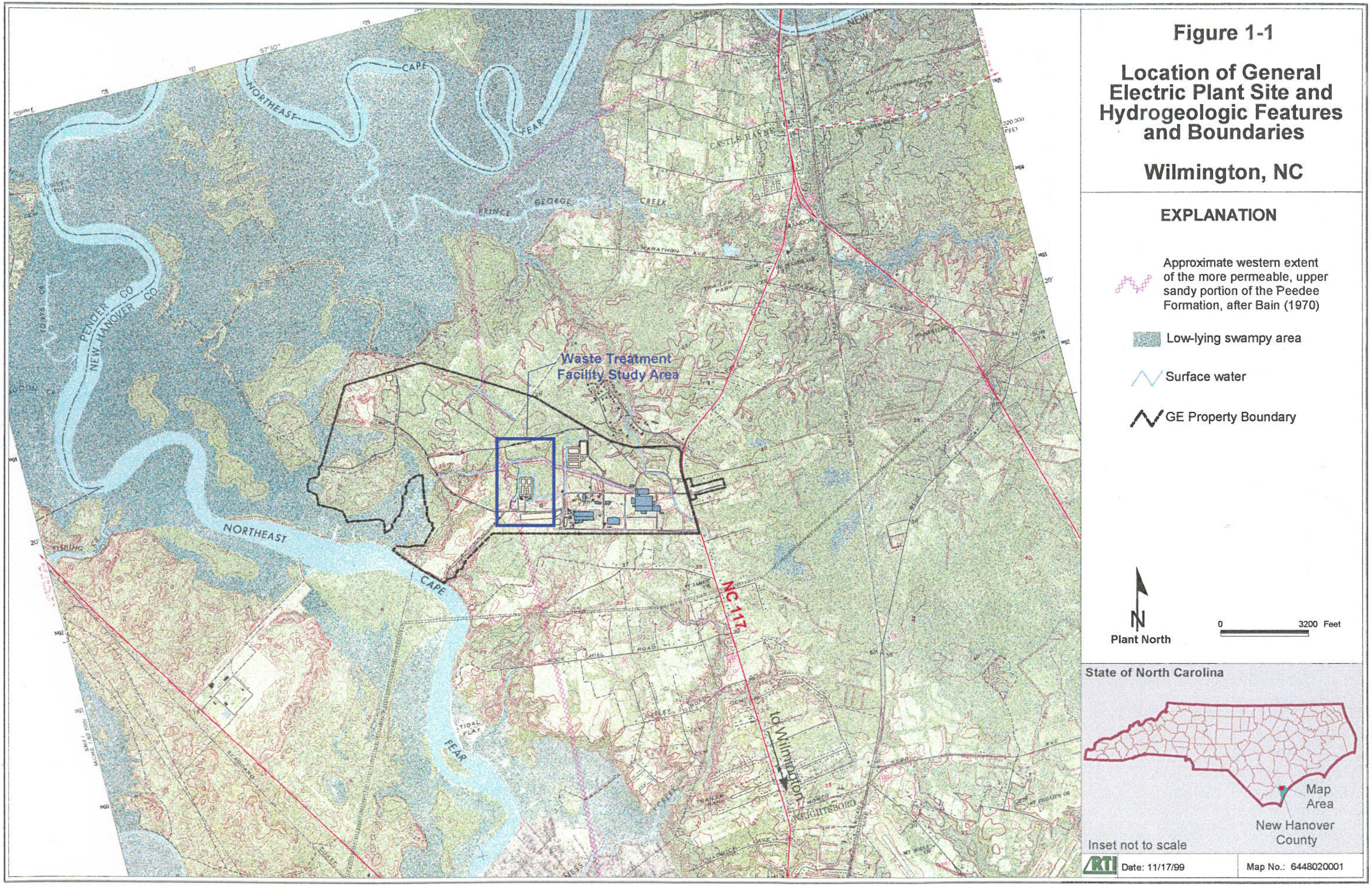
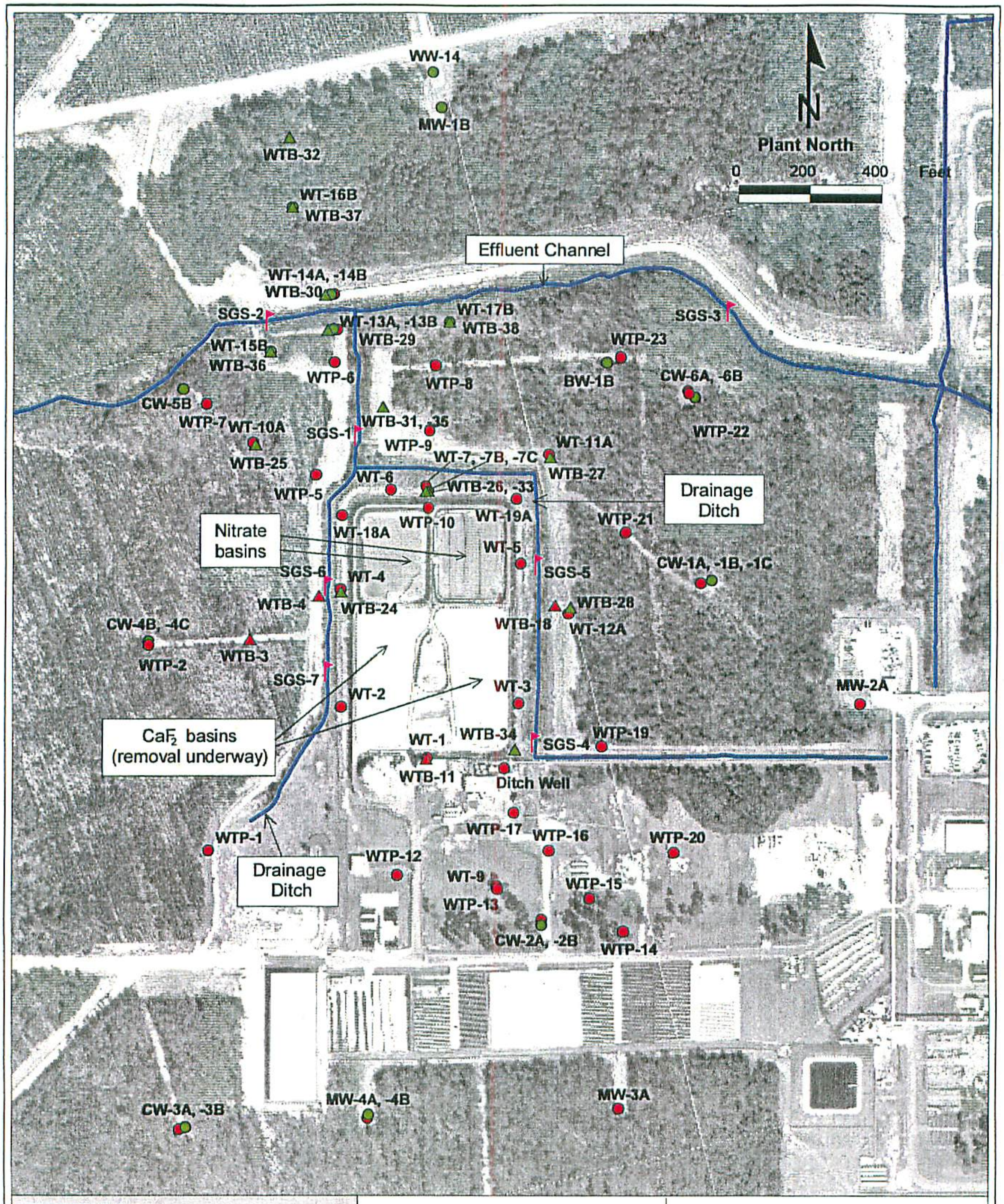


Figure 1-1

Location of General Electric Plant Site and Hydrogeologic Features and Boundaries

Wilmington, NC



Explanation

- ● Surficial-Aquifer Well/Piezometer
- ● Principal-Aquifer Well
- ▲ Surficial-Aquifer Boring
- ▲ Principal-Aquifer Boring
- Stream-Gauging Station
- Drainage Ditch/Effluent Channel

Figure 1-2

WT Area Hydrogeologic Investigation Sampling Locations

GE - Wilmington, NC Site

RTI | Date: 11/10/99 | Map No.: 6448020003

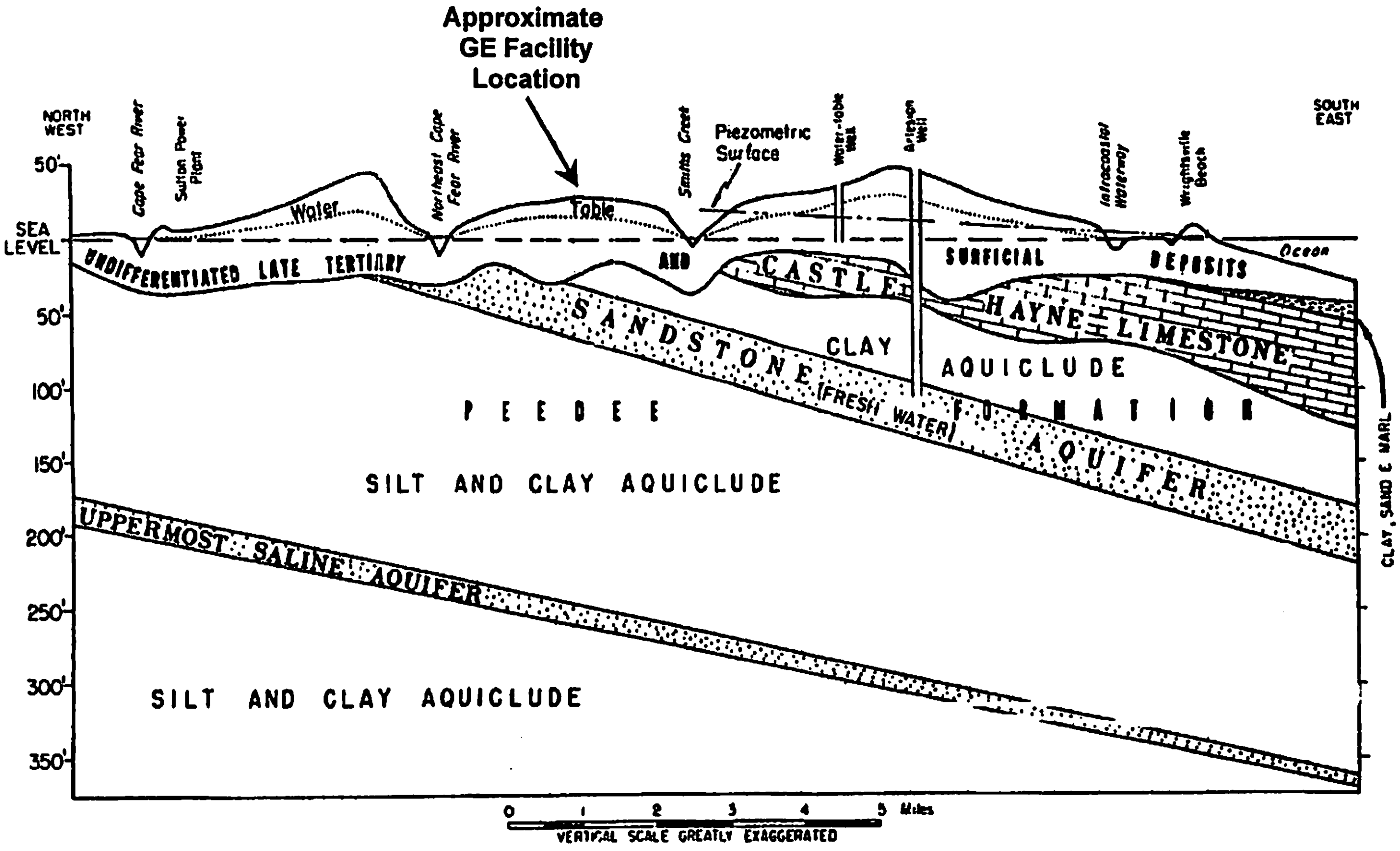


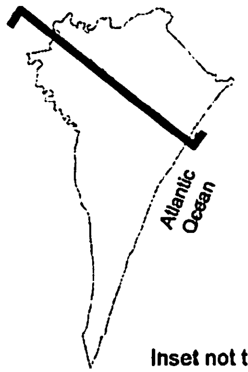
Figure 3-1

Geologic Cross Section through New Hanover County

WT Area
GE - Wilmington, NC Site

Note:
Cross section designed after Bain (1970)

New Hanover County, North Carolina
Approximate cross section location



Inset not to scale

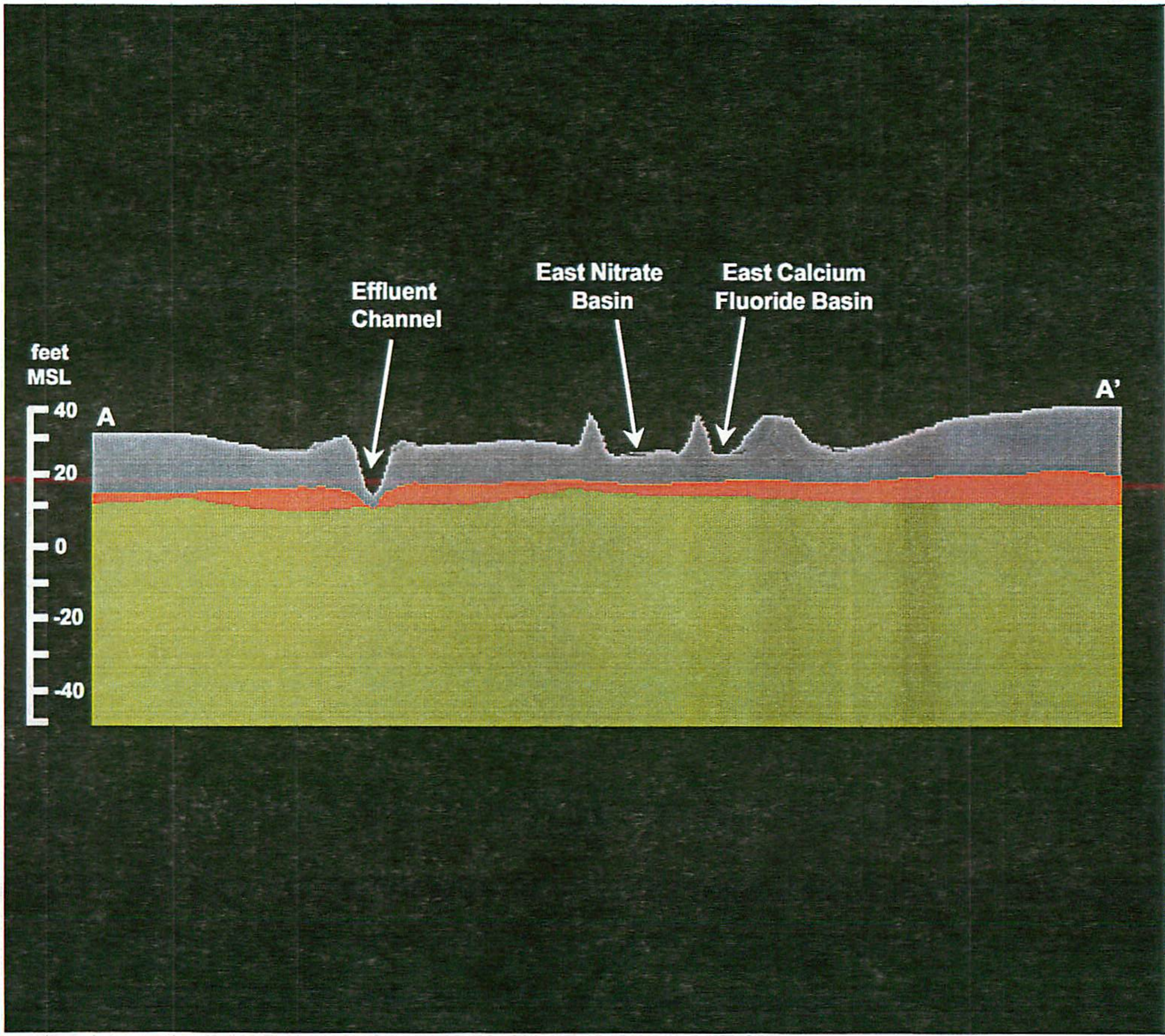
RTI

Project: 6448-020
Date: 11/17/99
File: Fig 3-1.ppt

Figure 3-2

Northwest-Southeast Hydrogeologic Cross Section A-A'

WT Area
GE - Wilmington, NC Site



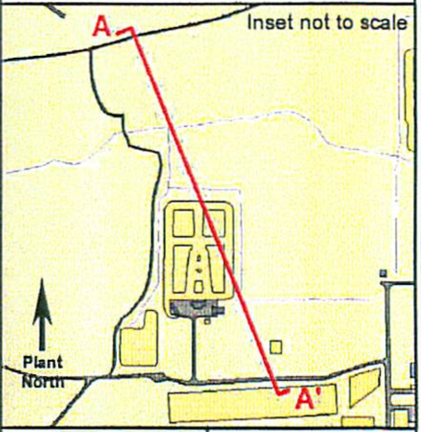
Explanation

▨	Surficial Aquifer
🟥	Semiconfining Layer
🟩	Principal Aquifer

Notes:

Thicknesses and elevations of the geologic units were interpolated from field lithologic data (see Appendix C) using a linear kriging procedure.

The vertical exaggeration is 10X.



Project: 6448-020
Date: 11/17/99
File: Fig 3-2.ppt

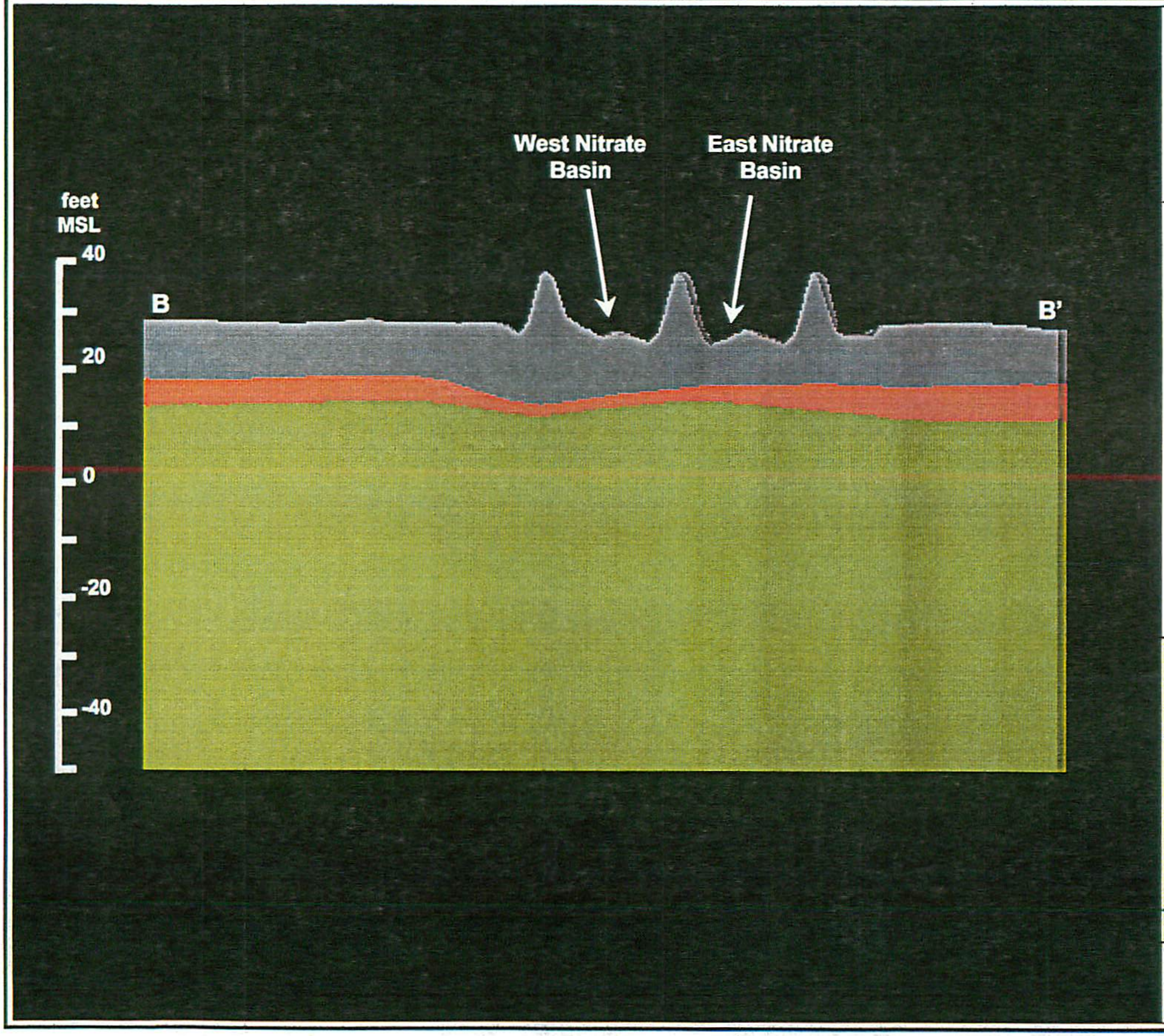


Figure 3-3

Southwest-Northeast Hydrogeologic Cross Section B-B'

WT Area
GE - Wilmington, NC Site

Explanation

▨ Surficial Aquifer

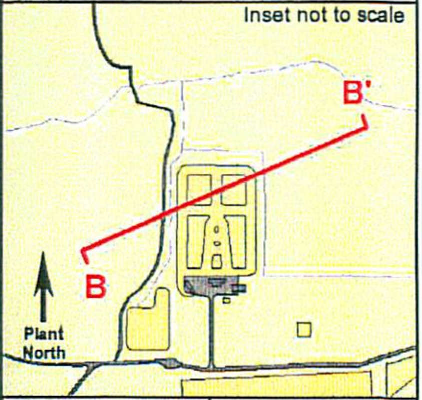
🟥 Semiconfining Layer

🟩 Principal Aquifer

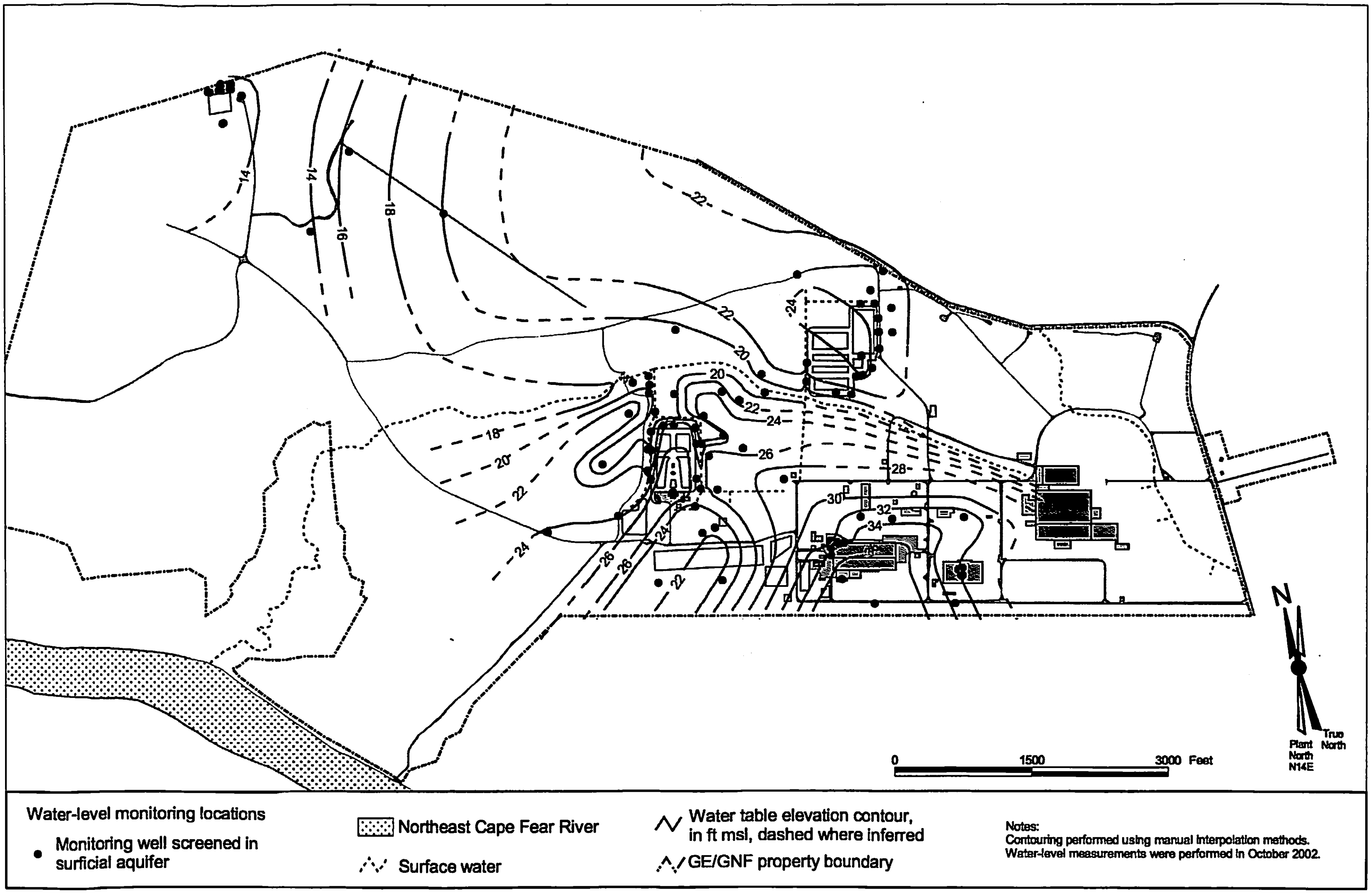
Notes:

Thicknesses and elevations of the geologic units were interpolated from field lithologic data (see Appendix C) using a linear kriging procedure.

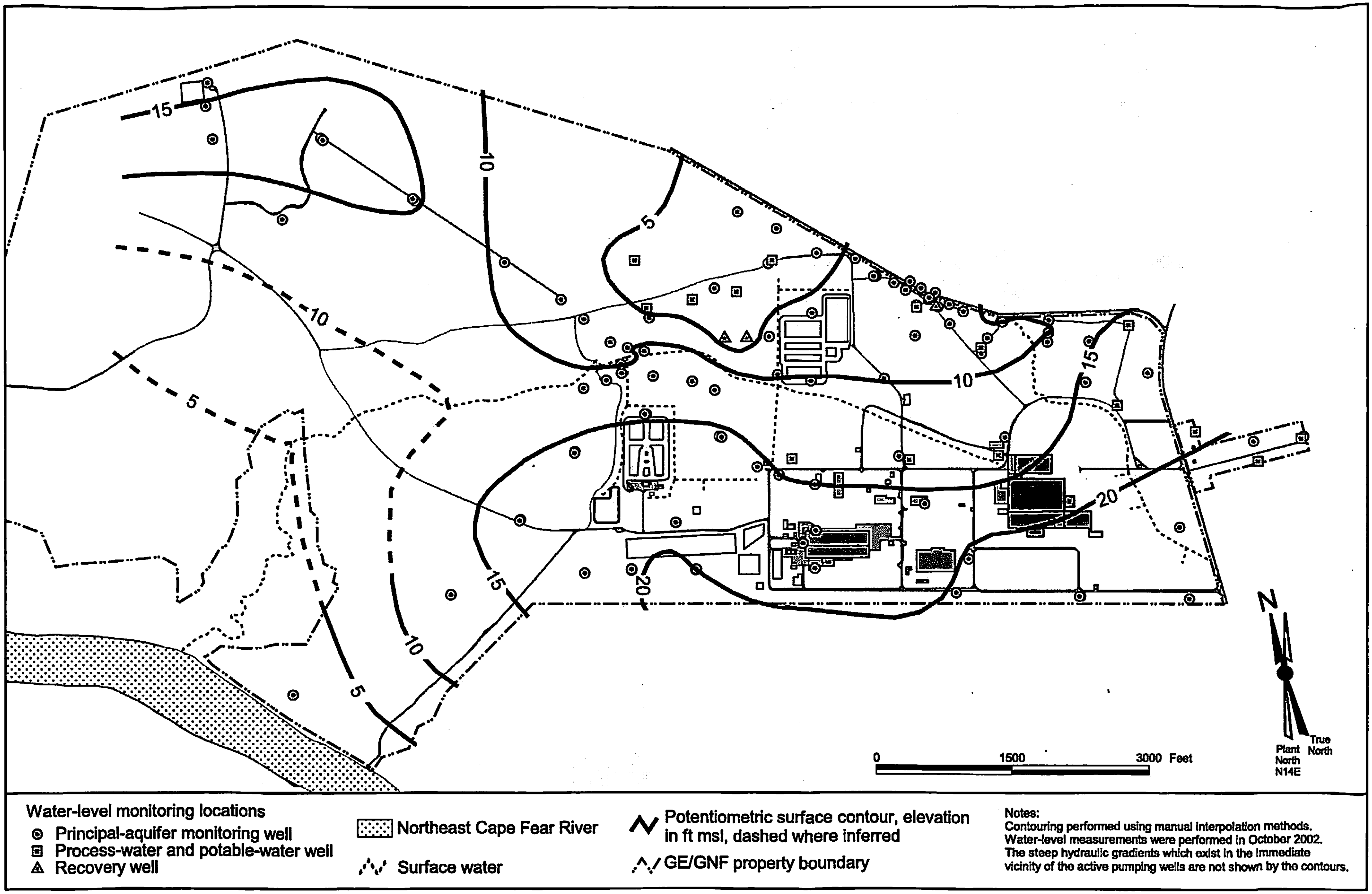
The vertical exaggeration is 10X.



Project: 6448-020
Date: 11/17/99
File: Fig 3-2.ppt

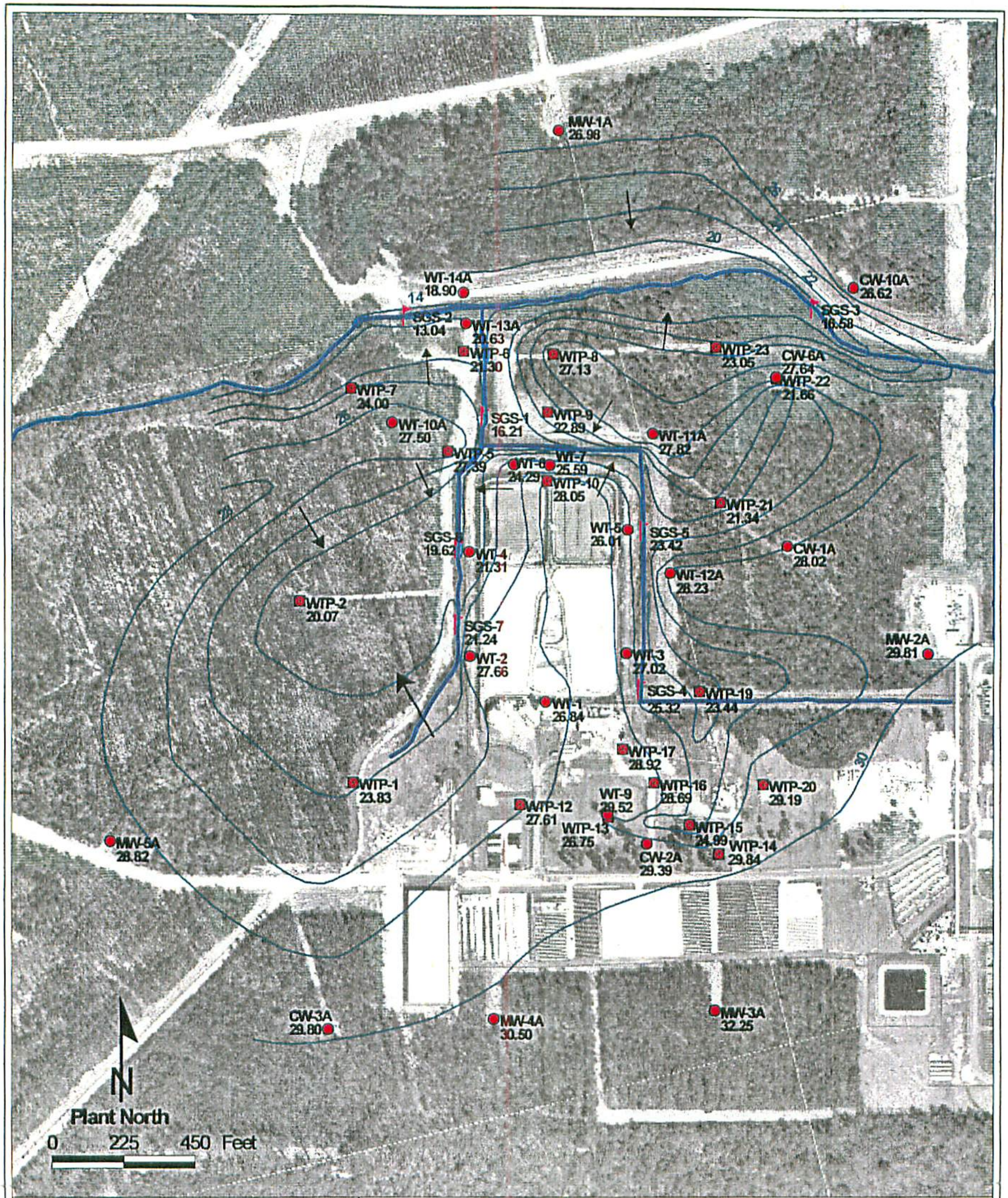


Generalized Water Table of Surficial Aquifer

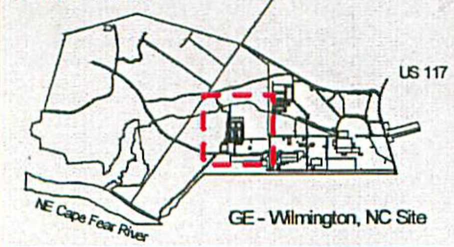


Notes:
Contouring performed using manual interpolation methods.
Water-level measurements were performed in October 2002.
The steep hydraulic gradients which exist in the immediate vicinity of the active pumping wells are not shown by the contours.

Generalized Potentiometric Surface of Principal Aquifer



INSET NOT TO SCALE



RTI | Date: July 27, 1999 | Map No.: 6448019004

Explanation

- ● Surficial-Aquifer Well
- ▣ Surficial-Aquifer Piezometer
- Stream-Gauging Station
- Drainage Ditch/Effluent Channel
- Line of Equal Water Level (feet above mean sea level)
- ↗ Groundwater Flow Direction

Figure 3-4

Groundwater Elevations in the Surficial Aquifer Measured 5/5/99

WT Area
GE - Wilmington, NC Site

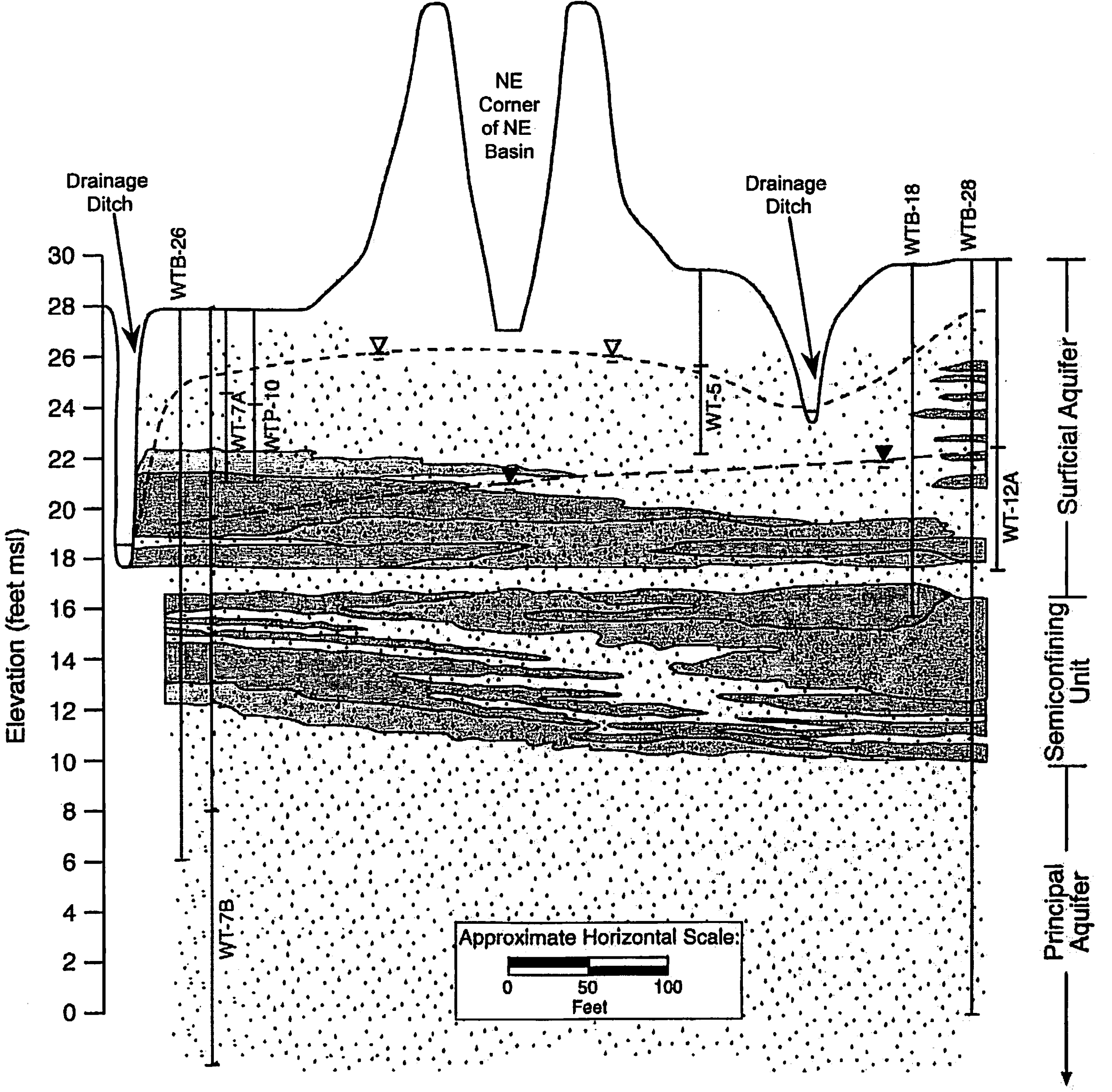


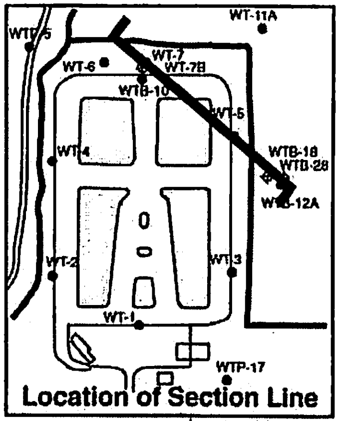
Figure 3-5

Detailed Southwest-Northeast Hydrogeologic Cross Section Through the Northeast WT Basin

WT Area
GE - Wilmington, NC Site

Explanation

⊡ Sand
⊡ Clayey Sand/Sandy Clay
▨ Clay
▼ Approximate Potentiometric Surface (Principal Aquifer)
▽ Approximate Surface of the Water Table (Surficial Aquifer)
WTB = Boring
WT = Well
WTP = Piezometer



Location of Section Line

Inset not to scale

RTI

Project: 6448-020
Date: 11/2/99
File: Fig 3-5.ppt

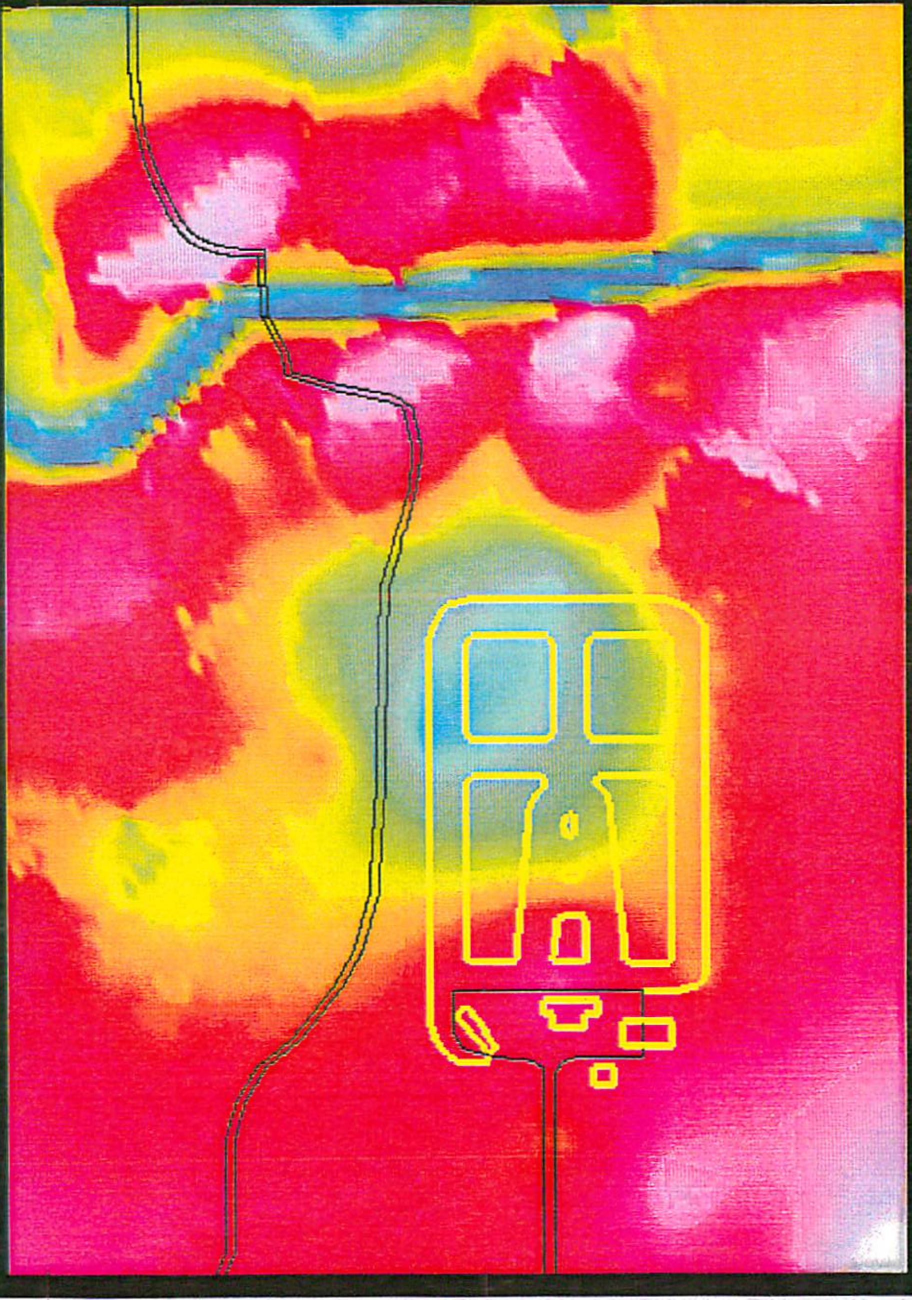


Figure 3-6

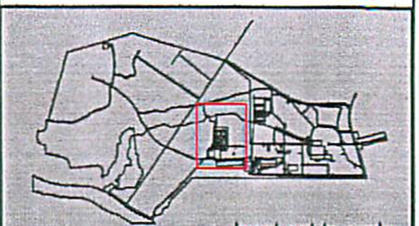
Thickness of the Semiconfining Layer

WT Area
GE - Wilmington, NC Site

Explanation

Thickness of the semiconfining layer in feet

Note: The thickness of the semiconfining layer was interpolated from field lithologic data (see Appendix C) using a linear kriging procedure.



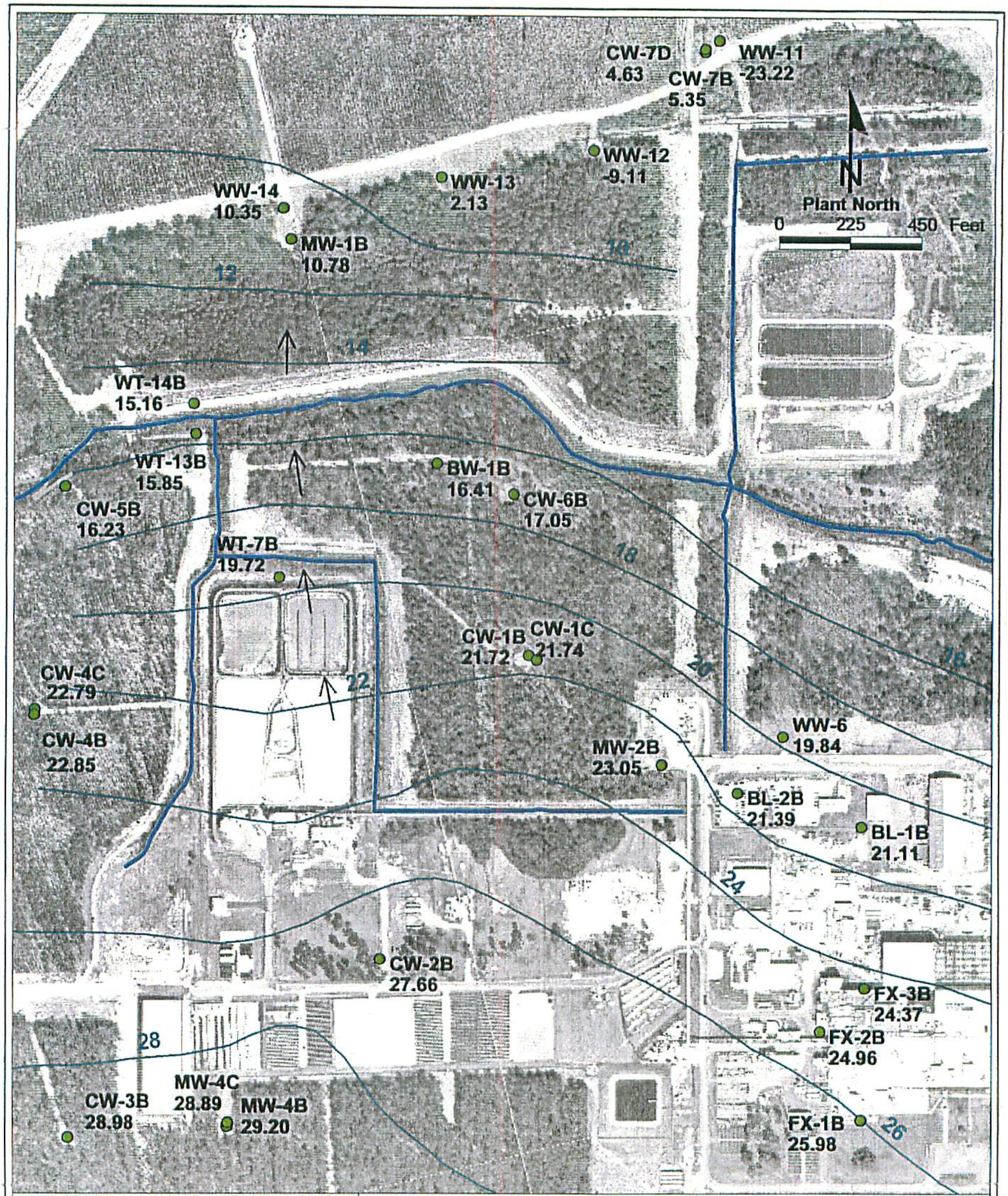
Inset not to scale

RTI

Project: 6448-020

Date: 11/2/99

File: Fig 3-6.ppt



RTI | Date: July 29, 1999 | Map No.: 6448019004

Explanation

● Principal-Aquifer Well

Drainage Ditch/Effluent Channel

Line of Equal Water Level (feet above mean sea level)

Groundwater Flow Direction

Figure 3-7

Groundwater Elevations in the Principal Aquifer Measured 5/5/99

WT Area
GE - Wilmington, NC Site

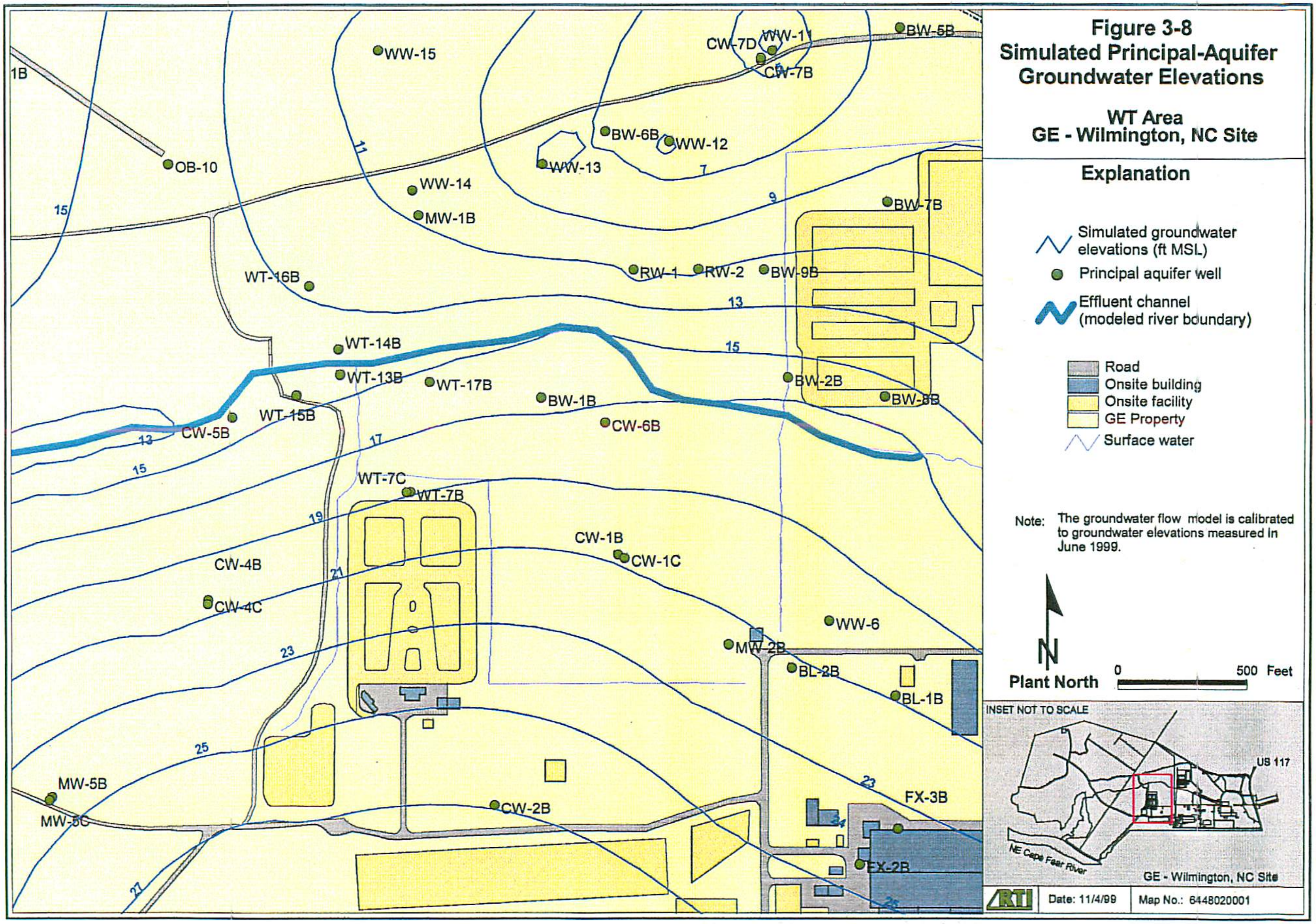


Figure 3-8
Simulated Principal-Aquifer Groundwater Elevations

WT Area
GE - Wilmington, NC Site

Explanation

╱╲	Simulated groundwater elevations (ft MSL)
●	Principal aquifer well
∿	Effluent channel (modeled river boundary)
▨	Road
▨	Onsite building
▨	Onsite facility
▨	GE Property
╱╲	Surface water

Note: The groundwater flow model is calibrated to groundwater elevations measured in June 1999.

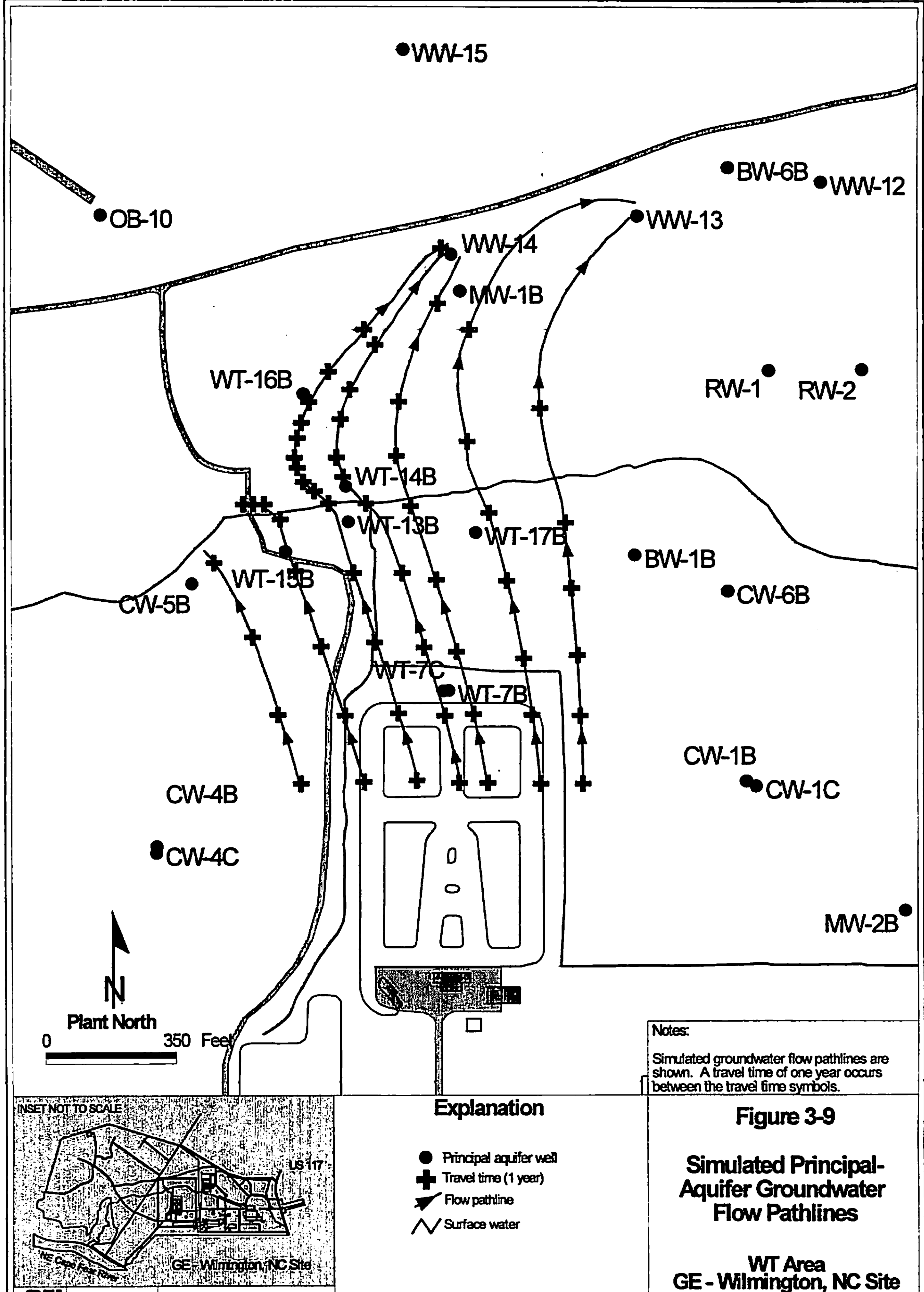
Plant North

0 500 Feet

RTI

Date: 11/4/99

Map No.: 6448020001



Notes:

Simulated groundwater flow pathlines are shown. A travel time of one year occurs between the travel time symbols.

Explanation

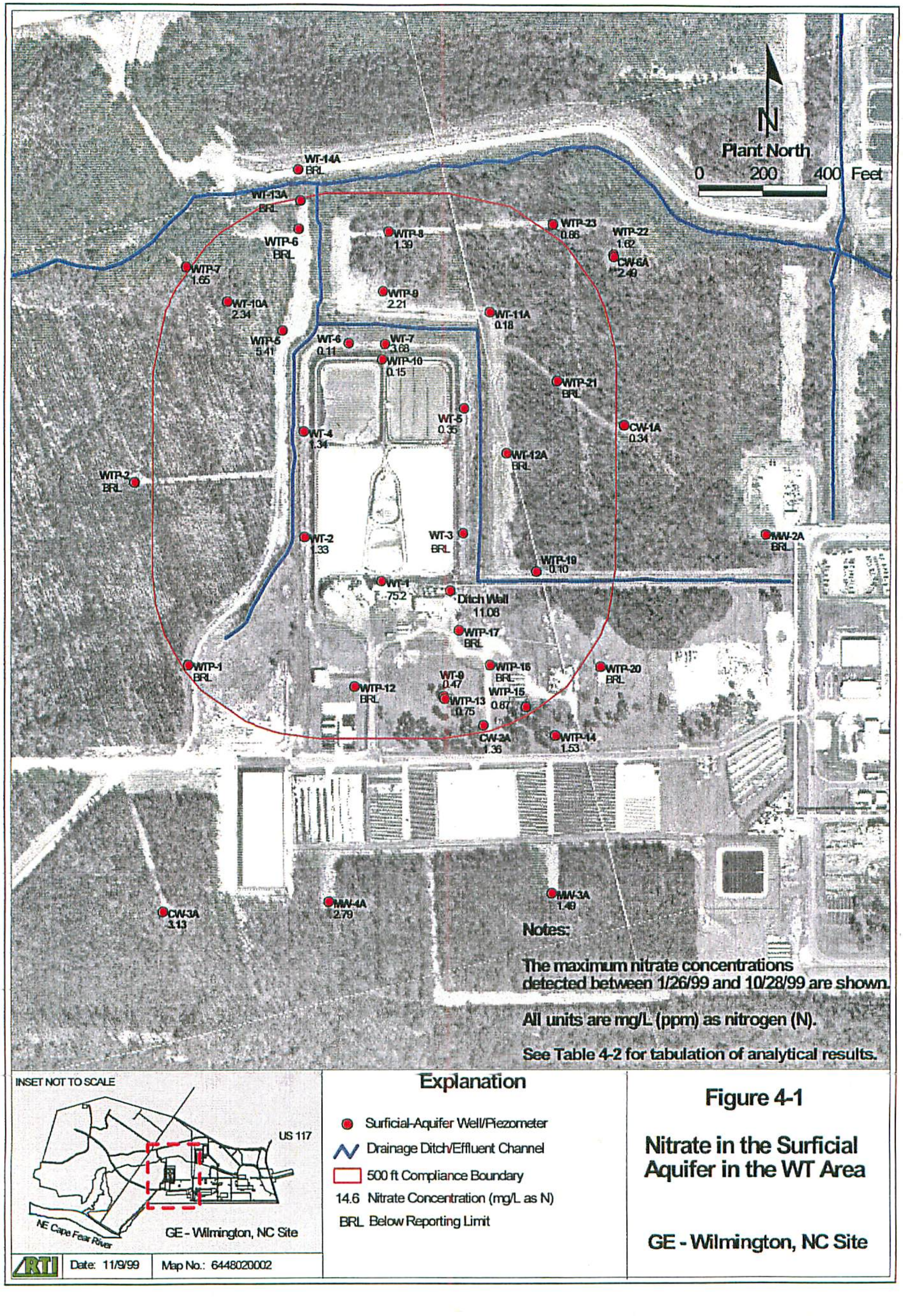
- ● Principal aquifer well
- ✚ Travel time (1 year)
- ➚ Flow pathline
- ╱╲╱ Surface water

Figure 3-9

Simulated Principal-Aquifer Groundwater Flow Pathlines

WT Area
GE - Wilmington, NC Site

RTI Date: 11/4/99 Map No.: 6448020001



Notes:

The maximum nitrate concentrations detected between 1/26/99 and 10/28/99 are shown.

All units are mg/L (ppm) as nitrogen (N).

See Table 4-2 for tabulation of analytical results.

Explanation

● Surficial-Aquifer Well/Piezometer

Drainage Ditch/Effluent Channel

500 ft Compliance Boundary

14.6 Nitrate Concentration (mg/L as N)

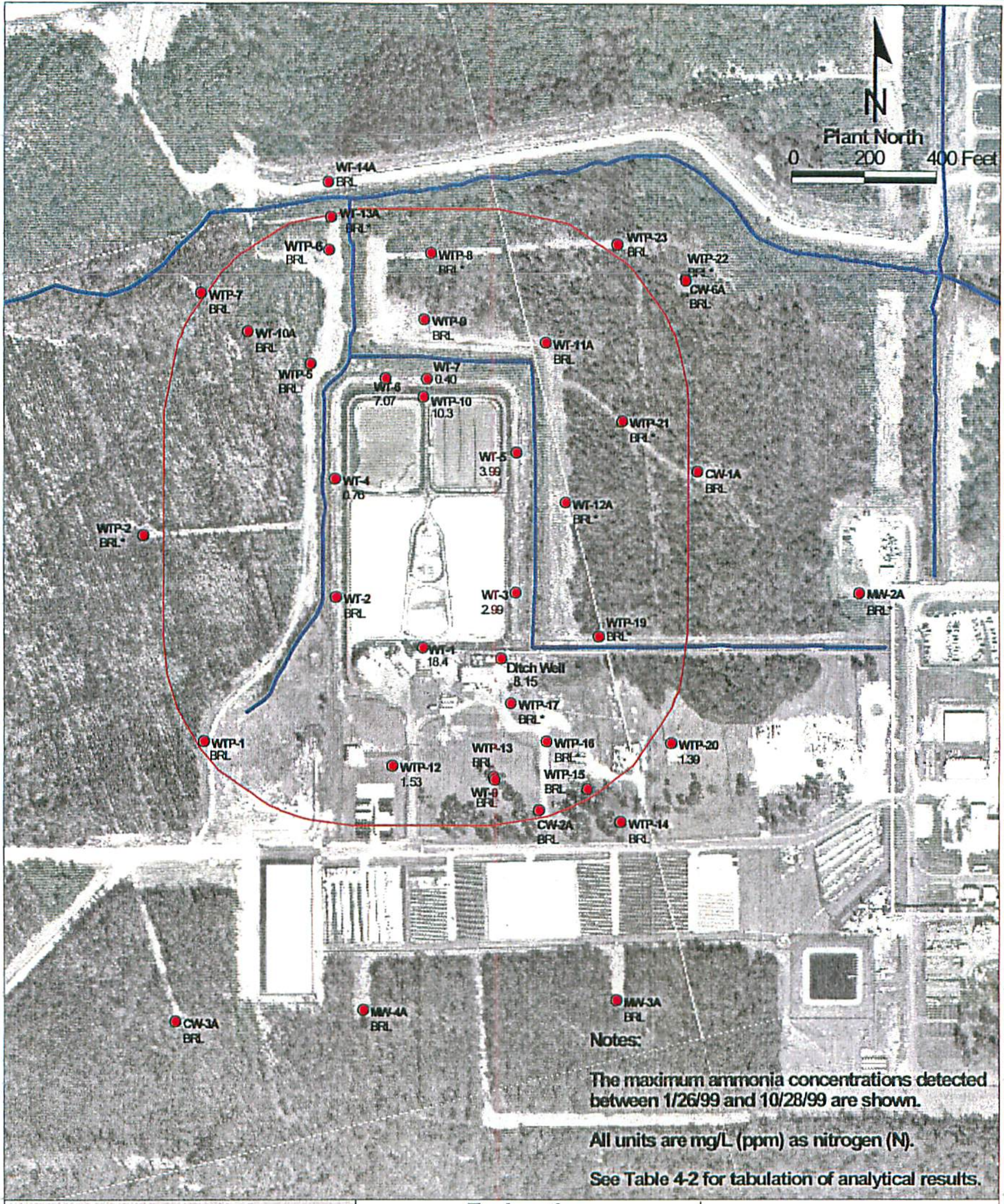
BRL Below Reporting Limit

Figure 4-1

Nitrate in the Surficial Aquifer in the WT Area

GE - Wilmington, NC Site

RTI Date: 11/9/99 Map No.: 6448020002



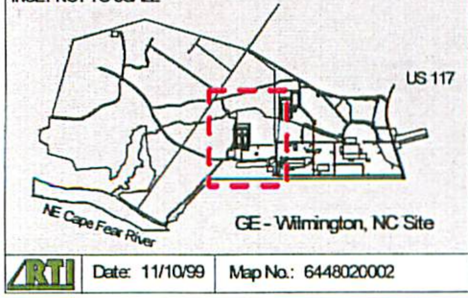
Notes:

The maximum ammonia concentrations detected between 1/26/99 and 10/28/99 are shown.

All units are mg/L (ppm) as nitrogen (N).

See Table 4-2 for tabulation of analytical results.

INSET NOT TO SCALE



RTI Date: 11/10/99 Map No.: 6448020002

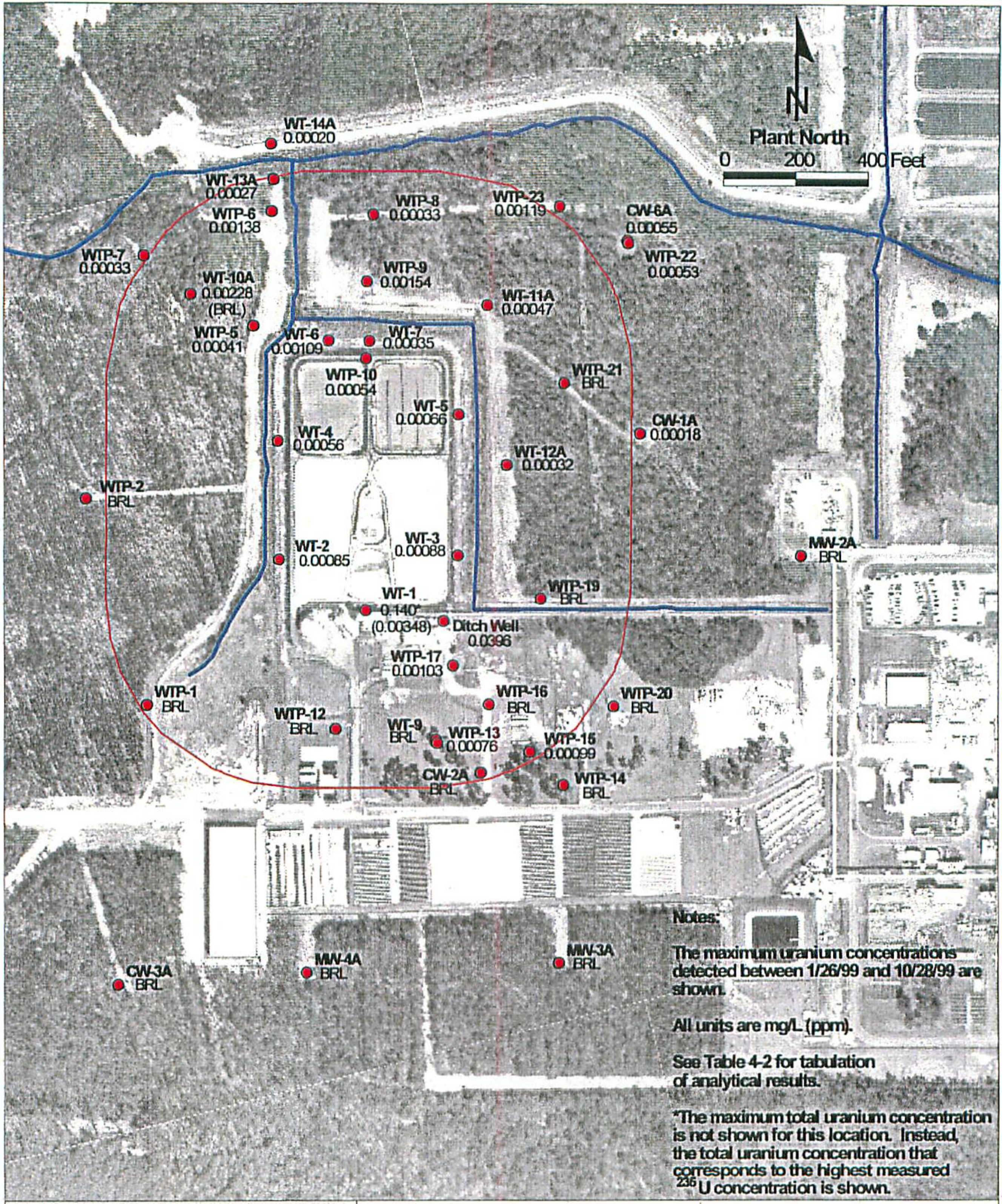
Explanation

- ● Surficial-Aquifer Well/Piezometer
- ☐ 500 ft Compliance Boundary
- ∕∕ Drainage Ditch/Effluent Channel
- 14.6 Ammonia Concentration (mg/L as N)
- BRL Below Reporting Limit
- * See Table 4-2 for explanation of data validation flag applied to analytical result

Figure 4-2

Ammonia in the Surficial Aquifer in the WT Area

GE - Wilmington, NC Site



Notes:

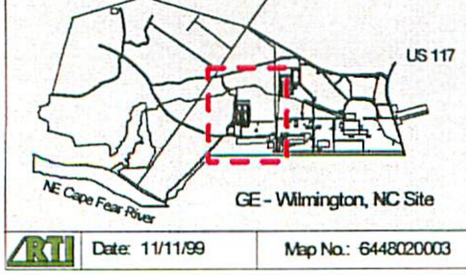
The maximum uranium concentrations detected between 1/26/99 and 10/28/99 are shown.

All units are mg/L (ppm).

See Table 4-2 for tabulation of analytical results.

*The maximum total uranium concentration is not shown for this location. Instead, the total uranium concentration that corresponds to the highest measured ^{235}U concentration is shown.

INSET NOT TO SCALE



RTI Date: 11/11/99 Map No.: 6448020003

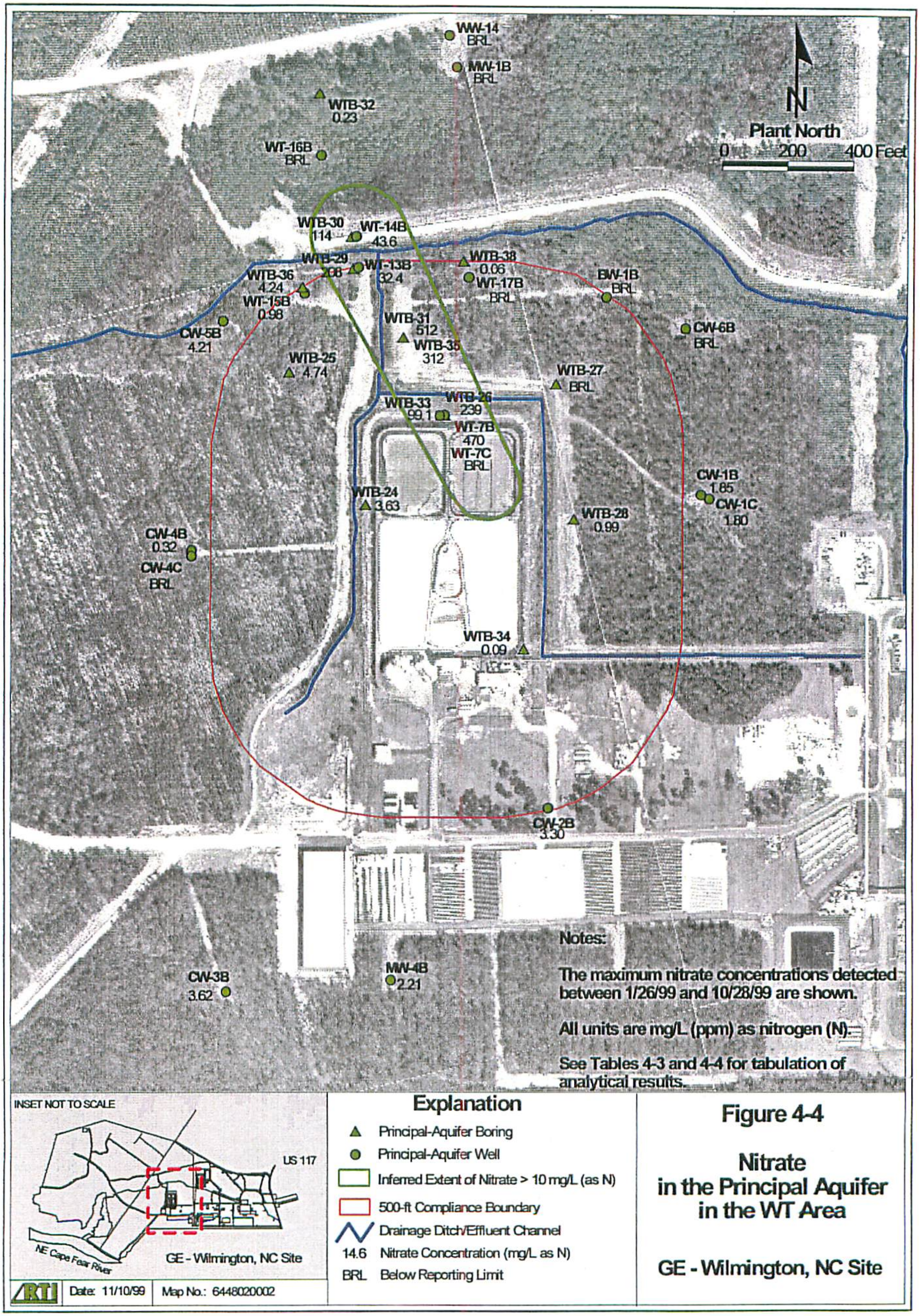
Explanation

●	Surficial-Aquifer Well/Piezometer
∕∖∕	Drainage Ditch/Effluent Channel
☐	500-ft Compliance Boundary
0.00154	Total Uranium Concentration (mg/L)
(0.00348)	Uranium Isotope 235 Concentration (mg/L)
BRL	Below Reporting Limit

Figure 4-3

Uranium in the Surficial Aquifer in the WT Area

GE - Wilmington, NC Site



Notes:

The maximum nitrate concentrations detected between 1/26/99 and 10/28/99 are shown.

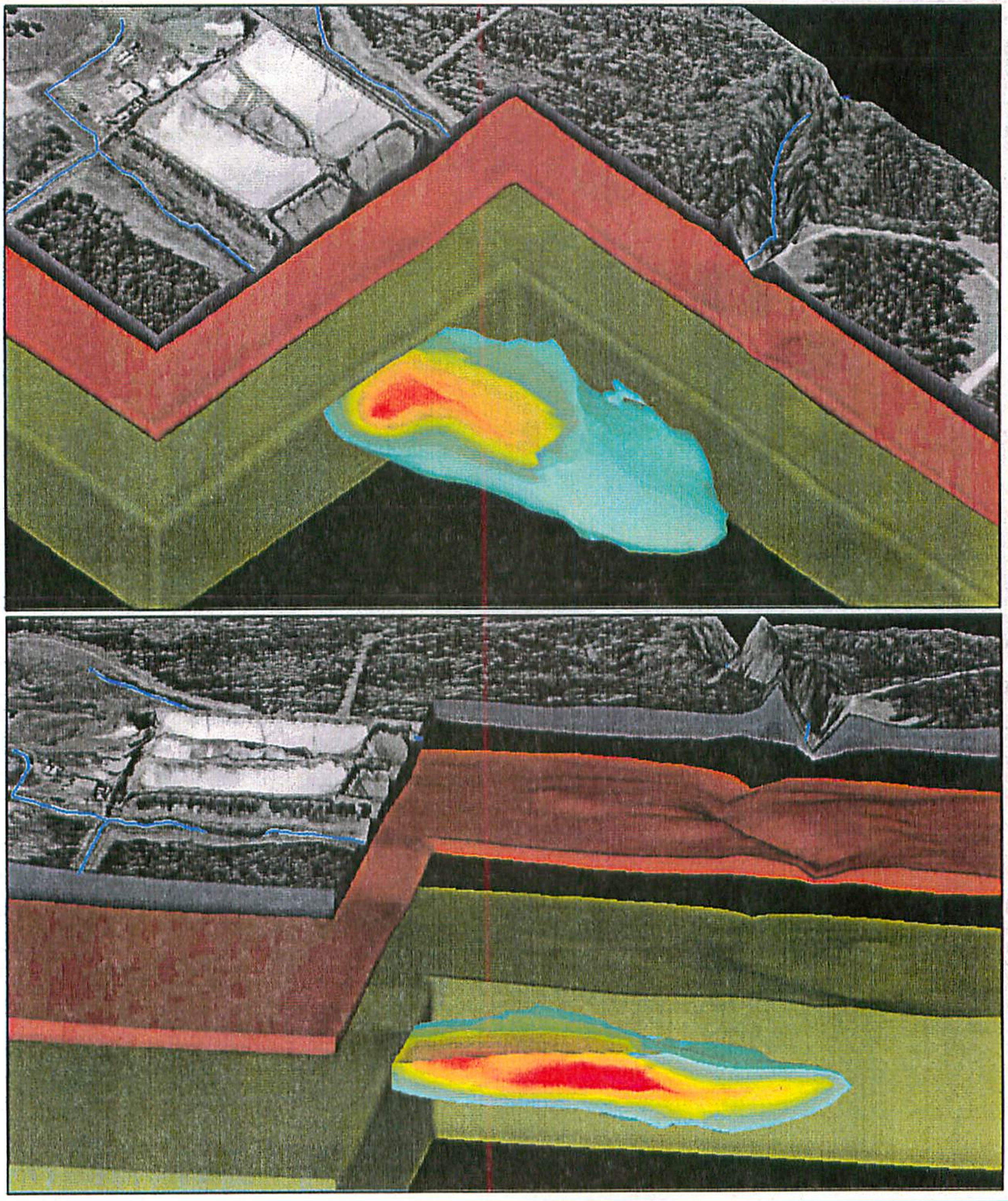
All units are mg/L (ppm) as nitrogen (N).

See Tables 4-3 and 4-4 for tabulation of analytical results.

Figure 4-4

Nitrate in the Principal Aquifer in the WT Area

GE - Wilmington, NC Site



Notes:
The upper image shows concentrations above 10 mg/L as N in the principal aquifer. The lower image shows the same concentrations but with a slice cutting through the centerline of the plume, showing the plume interior.
Vertical exaggeration: 5x
Distance between layers: 50 ft

RTI

Project: 6448-019

Date: 12/25/00

File: Fig 3-5.ppt

Explanation

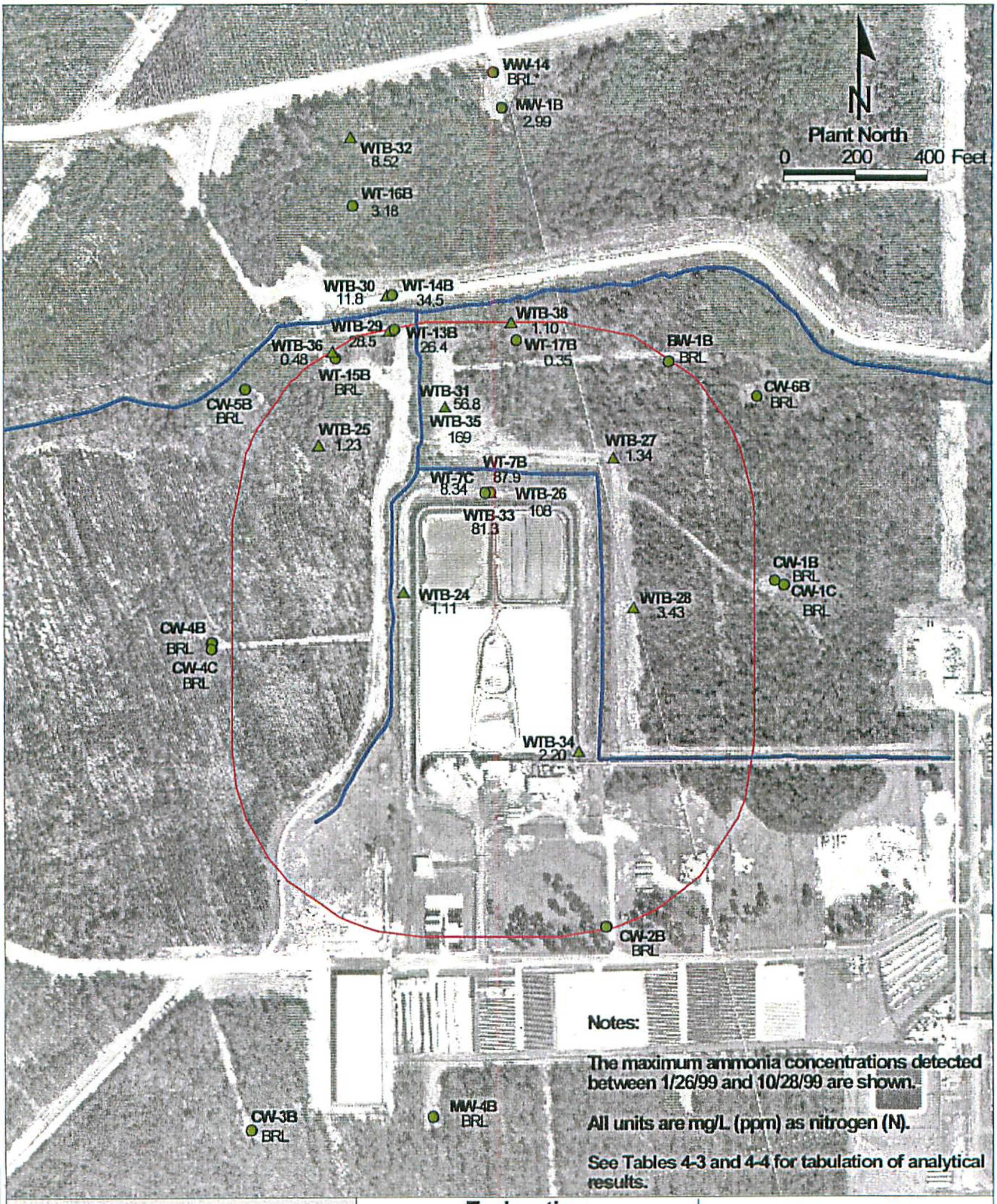
Nitrate concentration in mg/L as N

300 mg/L
200 mg/L
100 mg/L
50 mg/L
20 mg/L
10 mg/L

Figure 4-5

3-D Visualization of the Principal-Aquifer Nitrate Plume

WT Area
GE - Wilmington, NC Site



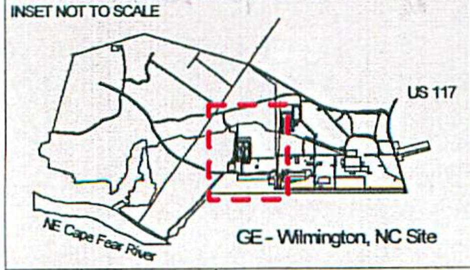
Notes:

The maximum ammonia concentrations detected between 1/26/99 and 10/28/99 are shown.

All units are mg/L (ppm) as nitrogen (N).

See Tables 4-3 and 4-4 for tabulation of analytical results.

INSET NOT TO SCALE



RTI Date: 11/11/99 Map No.: 6448020002

Explanation

▲ Principal-Aquifer Boring

● Principal-Aquifer Well

☐ 500-ft Compliance Boundary

╱╲ Drainage Ditch/Effluent Channel

1.5 Ammonia Concentration (mg/L as N)

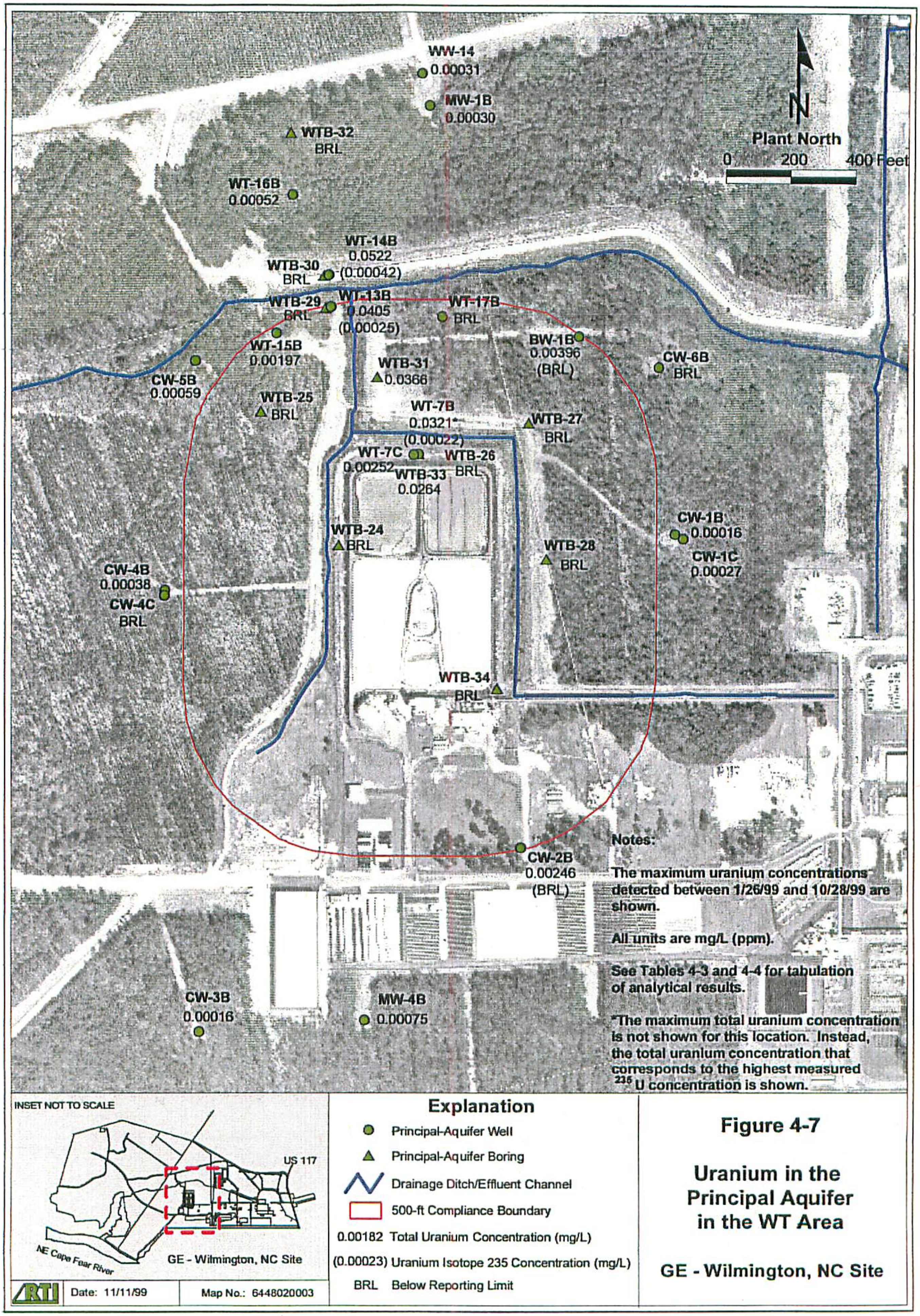
BRL Below Reporting Limit

* See Table 4-3 for explanation of data validation flag applied to analytical result

Figure 4-6

Ammonia in the Principal Aquifer in the WT Area

GE - Wilmington, NC Site



Notes:

The maximum uranium concentrations detected between 1/26/99 and 10/28/99 are shown.

All units are mg/L (ppm).

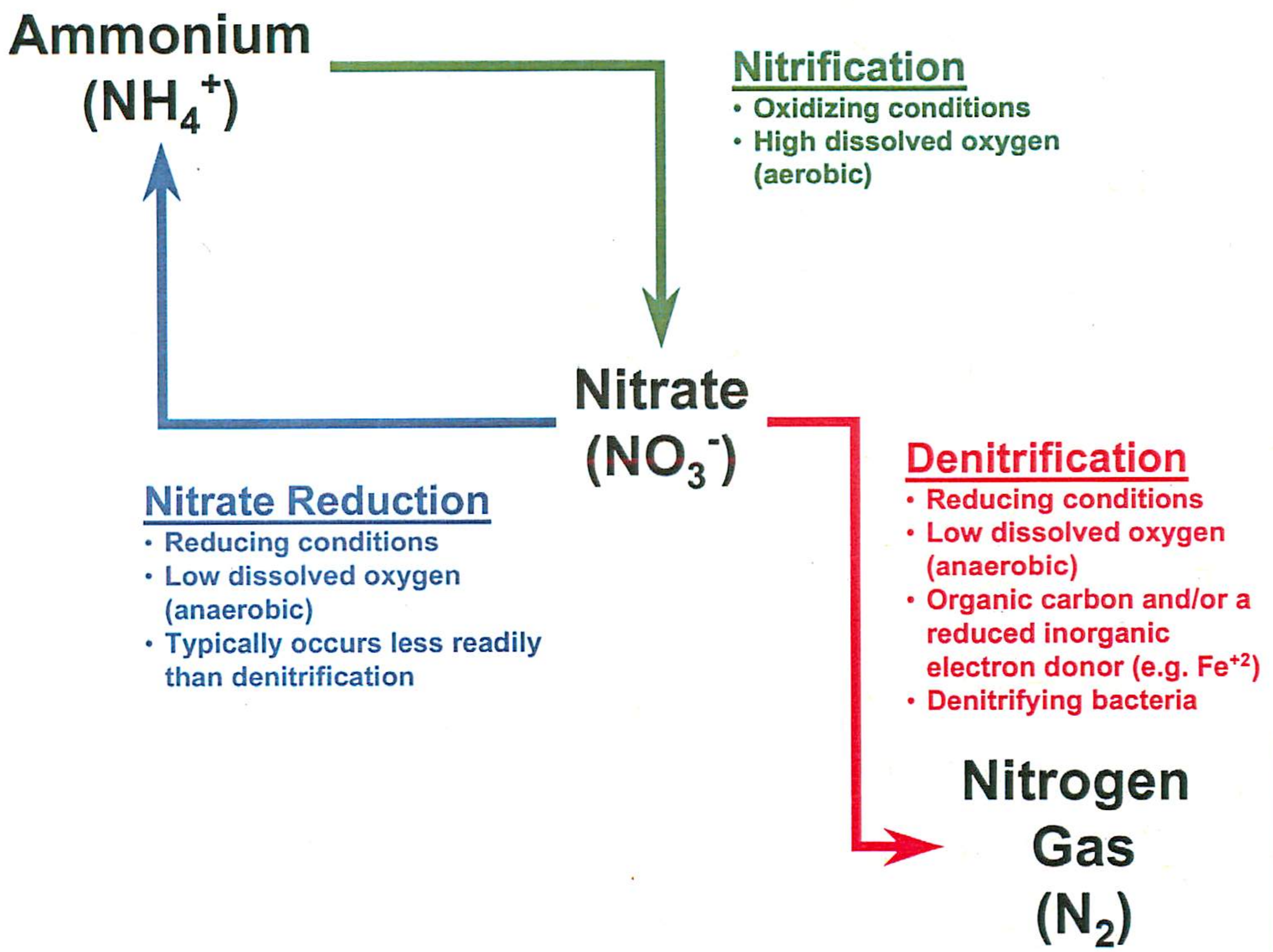
See Tables 4-3 and 4-4 for tabulation of analytical results.

*The maximum total uranium concentration is not shown for this location. Instead, the total uranium concentration that corresponds to the highest measured ^{235}U concentration is shown.

Figure 4-7

Uranium in the Principal Aquifer in the WT Area

GE - Wilmington, NC Site



Ammonium
(NH_4^+)

Nitrification
- Oxidizing conditions
- High dissolved oxygen (aerobic)

Nitrate
(NO_3^-)

Nitrate Reduction
- Reducing conditions
- Low dissolved oxygen (anaerobic)
- Typically occurs less readily than denitrification

Denitrification
- Reducing conditions
- Low dissolved oxygen (anaerobic)
- Organic carbon and/or a reduced inorganic electron donor (e.g. Fe^{+2})
- Denitrifying bacteria

Nitrogen
Gas
(N_2)

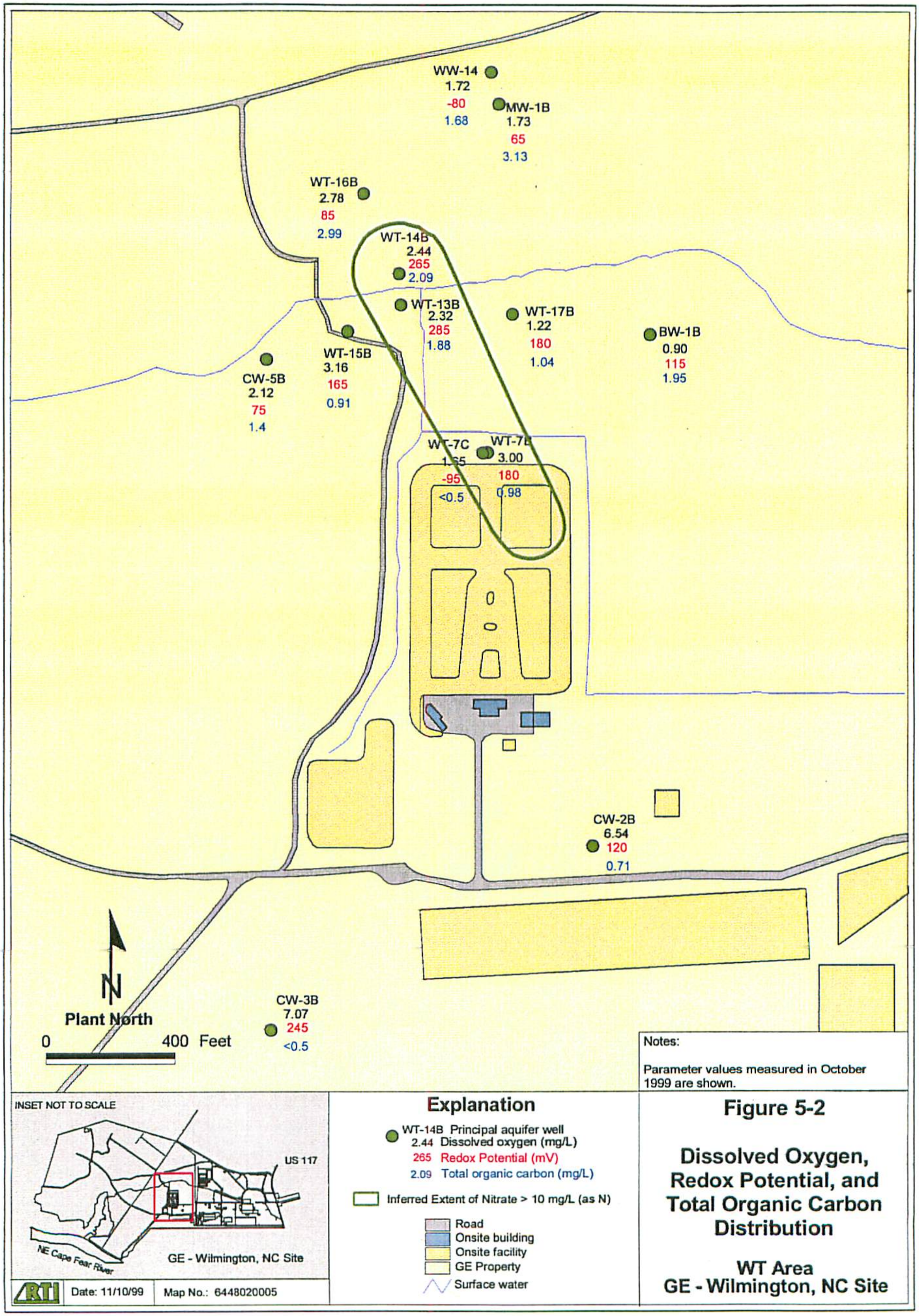
Figure 5-1

Potentially Relevant Aqueous Nitrogen Reactions

WT Area
GE - Wilmington, NC Site

RTI

Project: 6448-020
Date: 11/15/99
File: Figure 5-1.ppt



Notes:

Parameter values measured in October 1999 are shown.

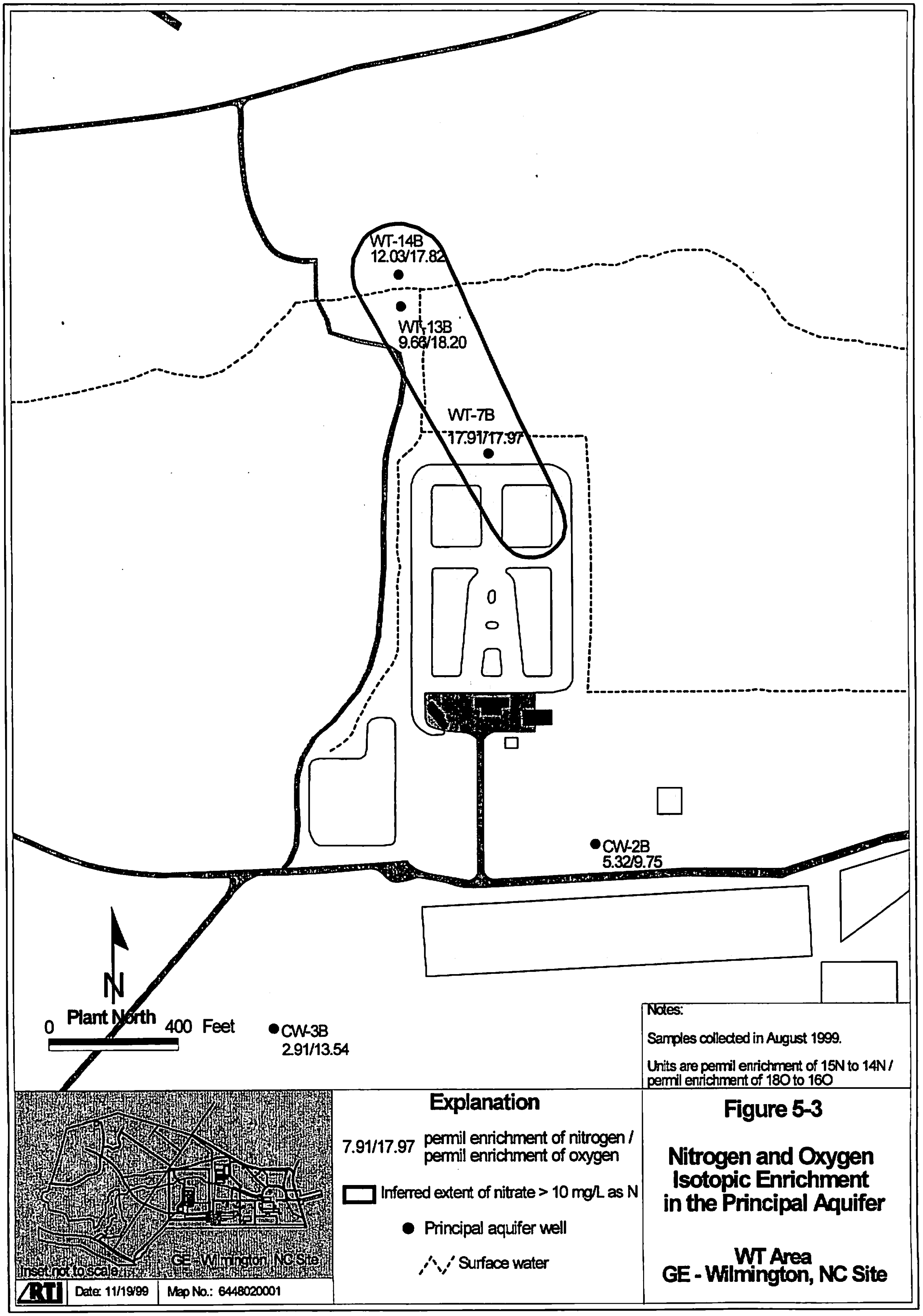
Date: 11/10/99

Map No.: 6448020005

Figure 5-2

Dissolved Oxygen, Redox Potential, and Total Organic Carbon Distribution

WT Area
GE - Wilmington, NC Site



Notes:

Samples collected in August 1999.

Units are permil enrichment of 15N to 14N / permil enrichment of 18O to 16O

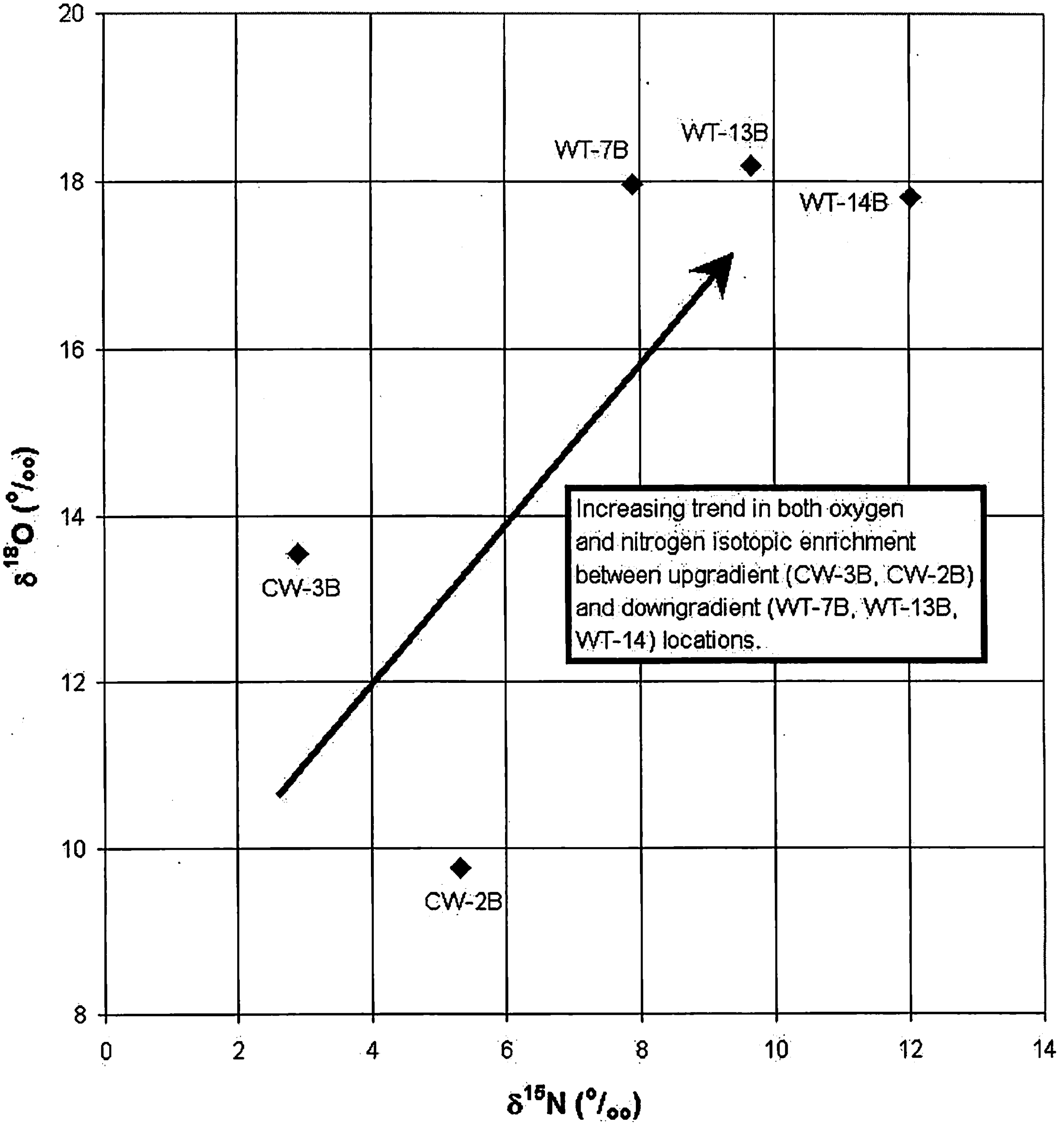
Explanation

7.91/17.97	permil enrichment of nitrogen / permil enrichment of oxygen
▭	Inferred extent of nitrate > 10 mg/L as N
●	Principal aquifer well
⁄\⁄	Surface water

Figure 5-3

Nitrogen and Oxygen Isotopic Enrichment in the Principal Aquifer

WT Area
GE - Wilmington, NC Site



Increasing trend in both oxygen and nitrogen isotopic enrichment between upgradient (CW-3B, CW-2B) and downgradient (WT-7B, WT-13B, WT-14) locations.

RTI

Project: 6448-019

Date: 11/19/99

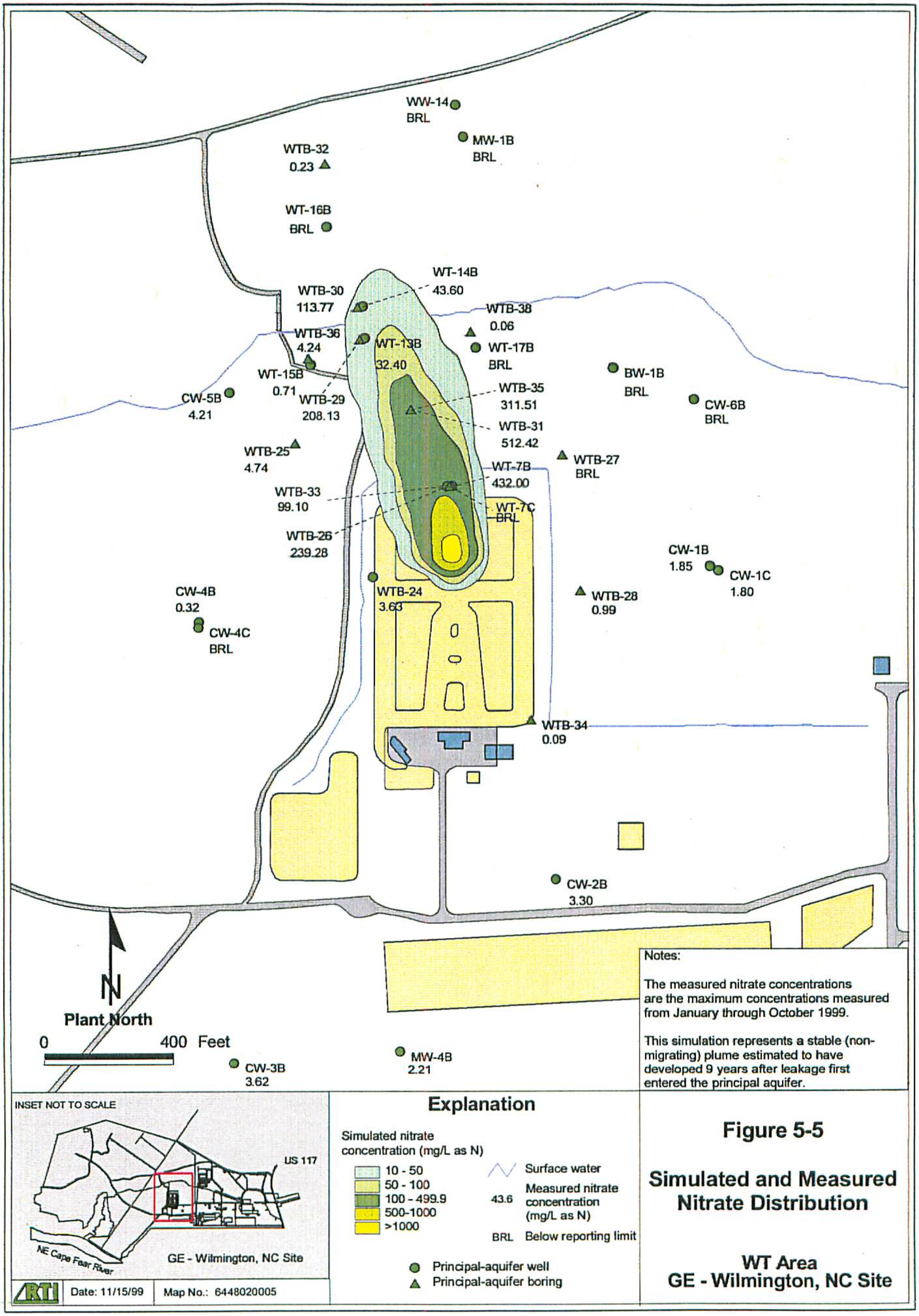
File: Fig 5-4.ppt

Notes:
Units are in permil enrichment of nitrogen and oxygen.

Figure 5-4

Nitrogen and Oxygen Isotopic Enrichment Trends in the Principal Aquifer

WT Area
GE - Wilmington, NC Site



Notes:

The measured nitrate concentrations are the maximum concentrations measured from January through October 1999.

This simulation represents a stable (non-migrating) plume estimated to have developed 9 years after leakage first entered the principal aquifer.

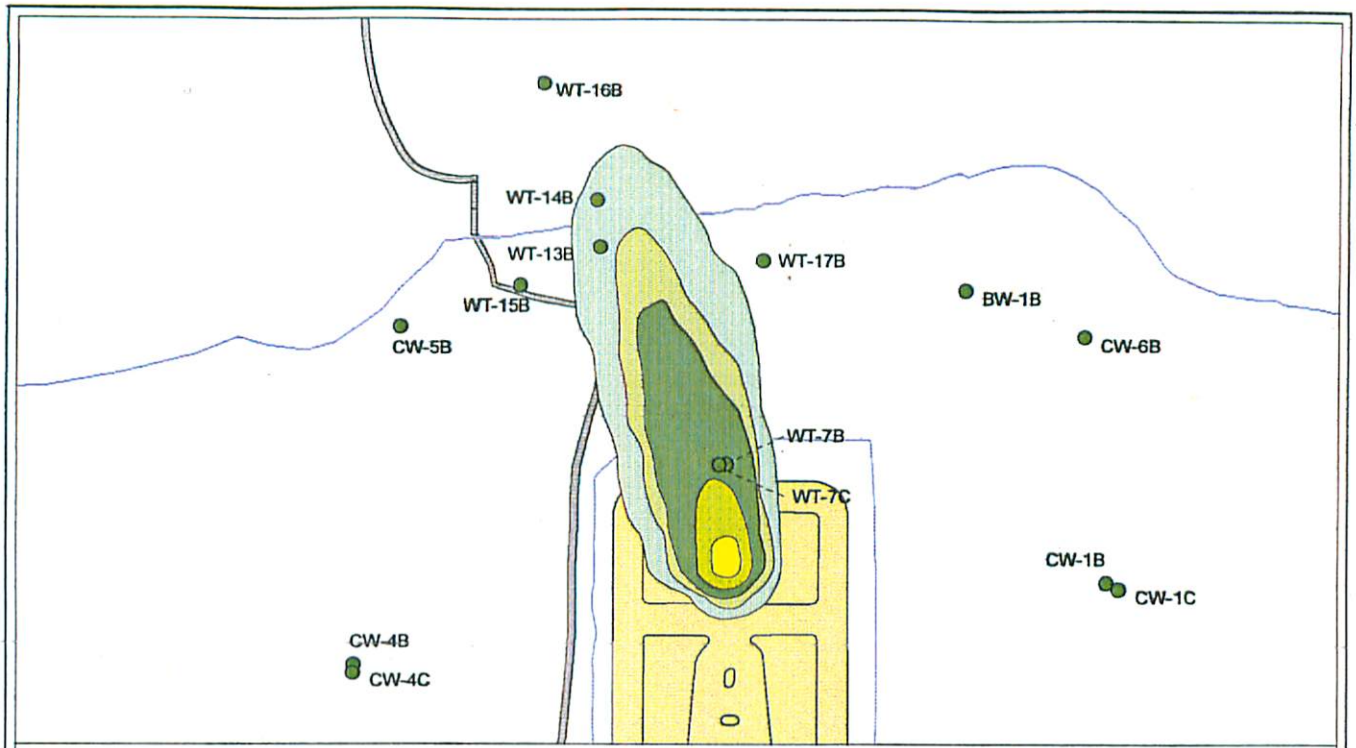
Date: 11/15/99

Map No.: 6448020005

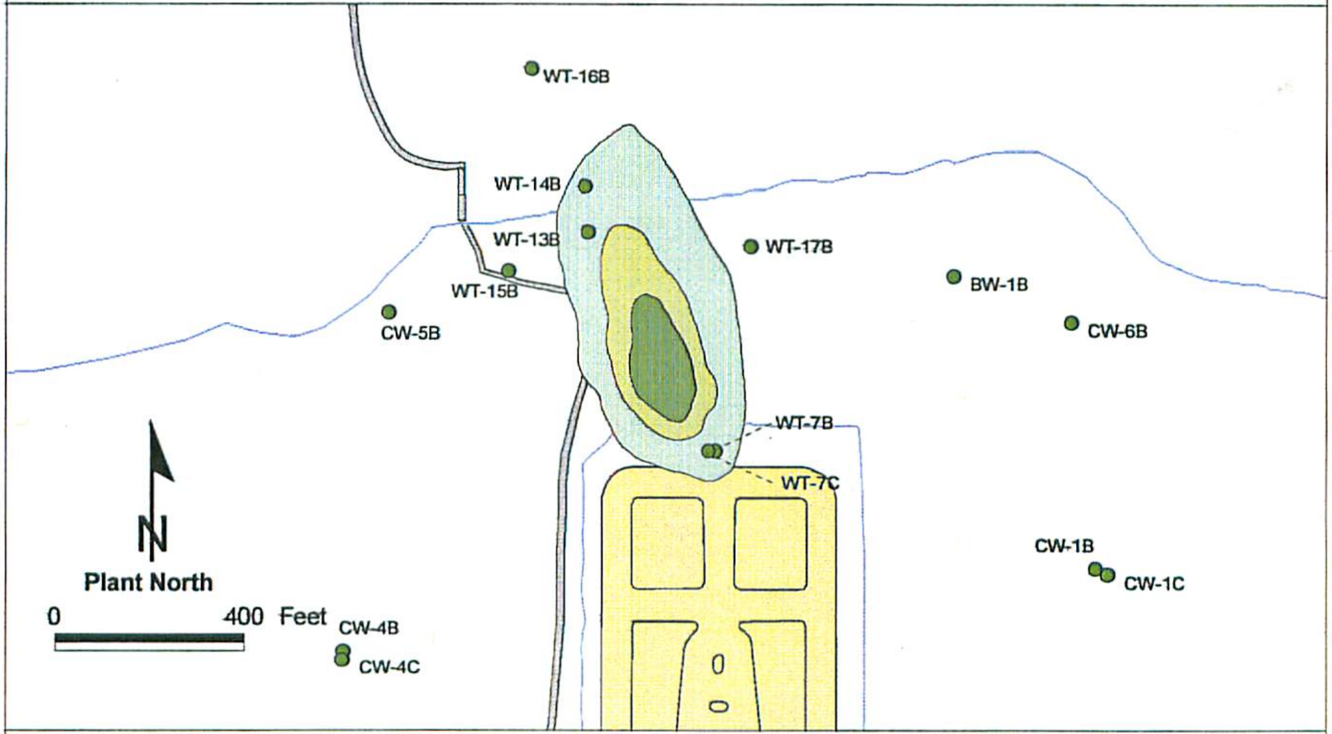
Figure 5-5

Simulated and Measured Nitrate Distribution

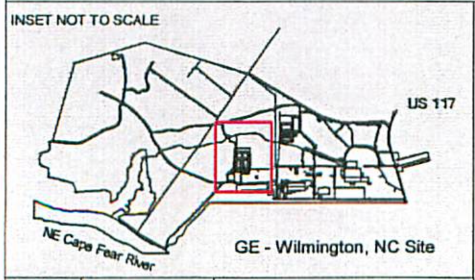
WT Area
GE - Wilmington, NC Site



Plume configuration 0 years after replacement of basin liners



Plume configuration 2 years after replacement of basin liners



RTI Date: 11/16/99 Map No.: 6448020005

Explanation

Simulated Nitrate Concentration (mg/L as N)

- ▨ 10 - 50
- ▨ 50 - 100
- ▨ 100 - 499.9
- ▨ 500-1000
- ▨ >1000

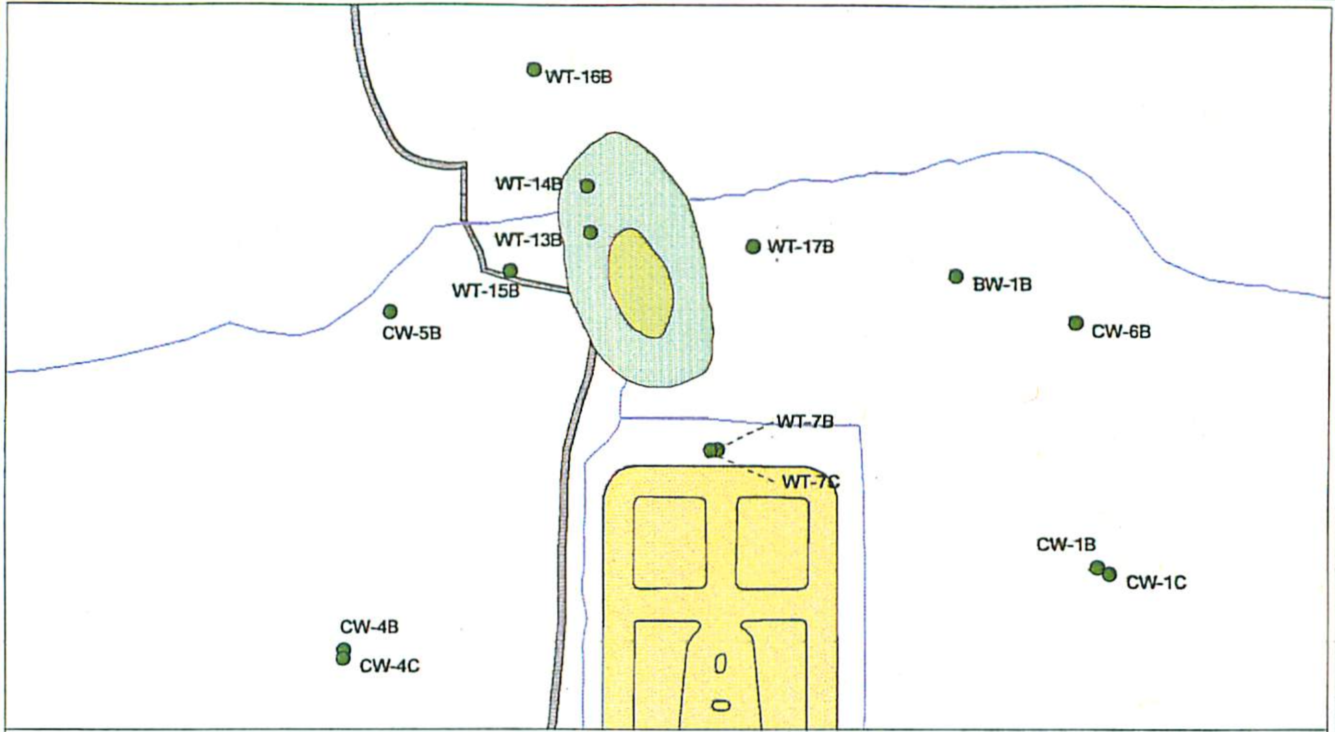
● WT-14B Principal aquifer well

Surface water

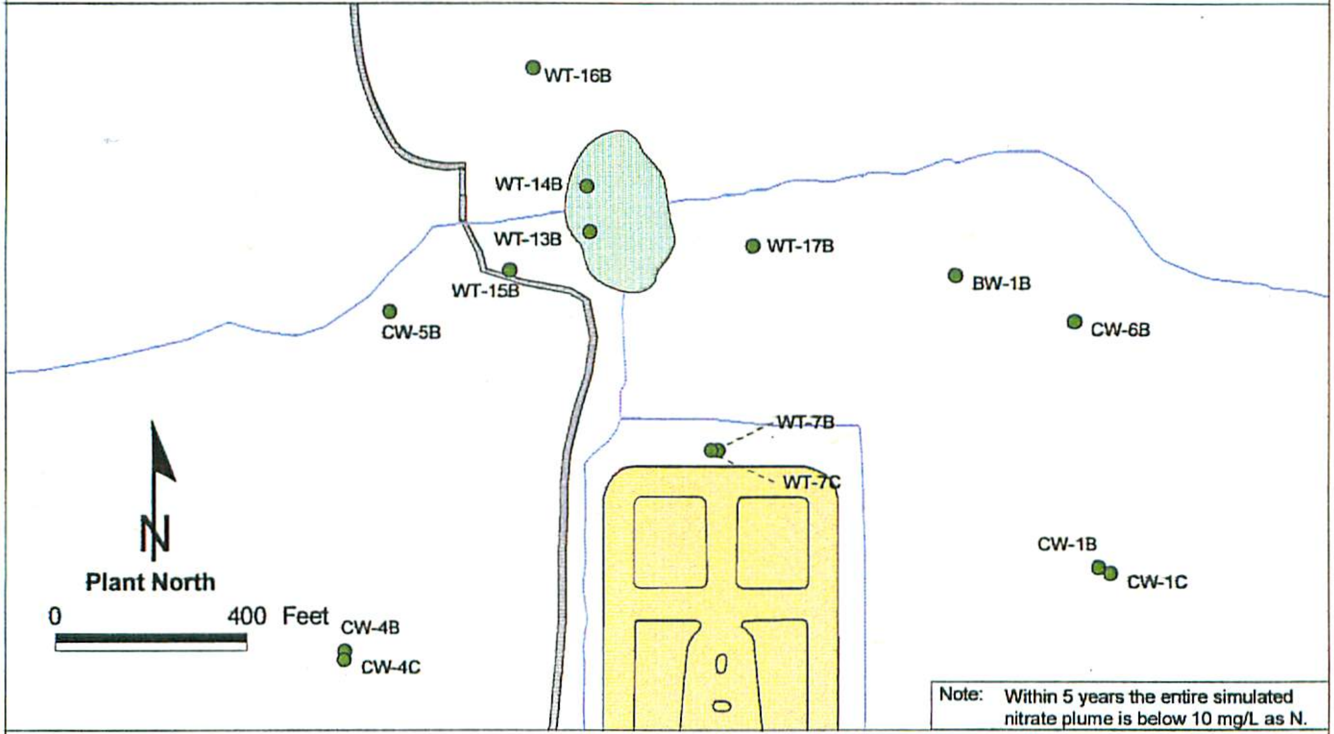
Figure 5-6

Nitrate Transport Model Scenario with Degradation – Years 0 through 2

WT Area
GE - Wilmington, NC Site

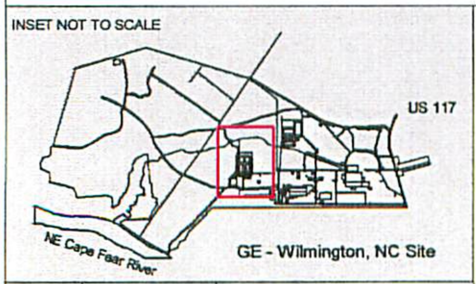


Plume configuration 3 years after replacement of basin liners



Note: Within 5 years the entire simulated nitrate plume is below 10 mg/L as N.

Plume configuration 4 years after replacement of basin liners



RTI Date: 11/16/99 Map No.: 6448020005

Explanation

Simulated Nitrate Concentration (mg/L as N)

▨ 10 - 50
▨ 50 - 100
▨ 100 - 499.9
▨ 500-1000
▨ >1000

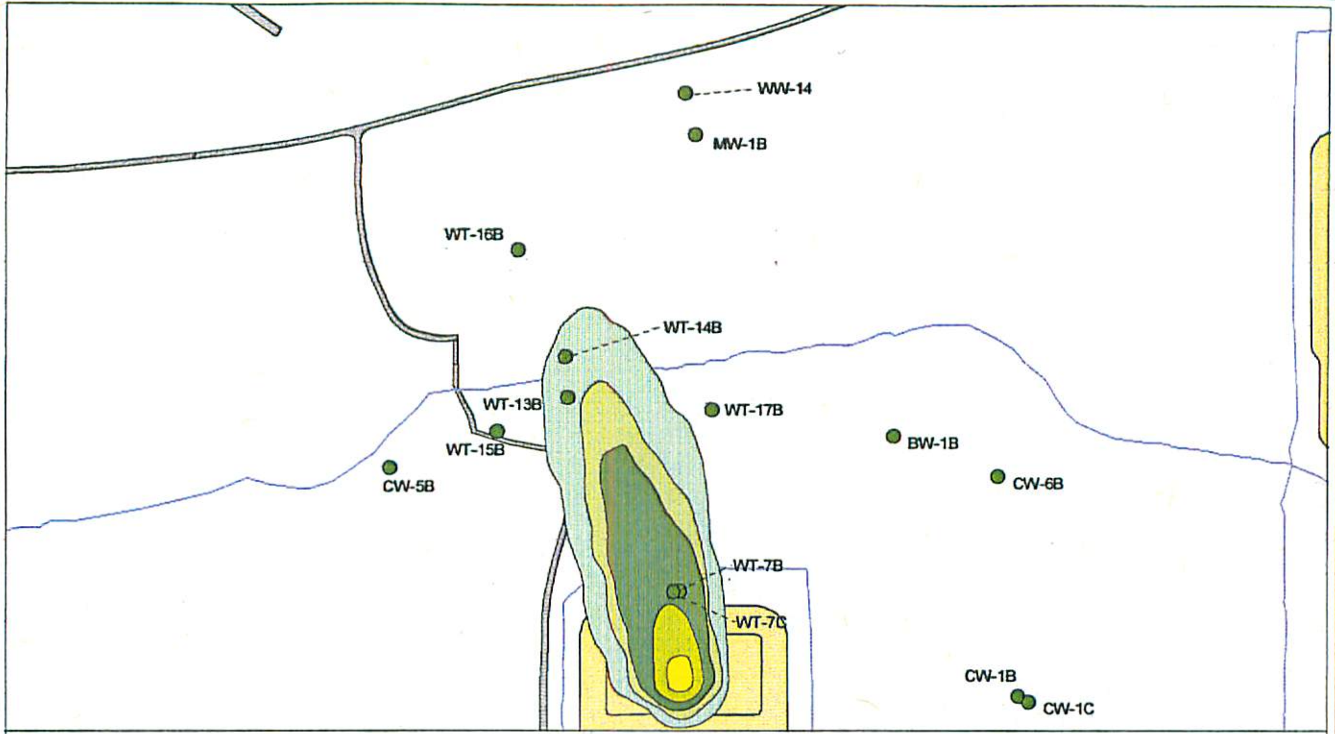
● WT-14B Principal aquifer well

╱╲╱ Surface water

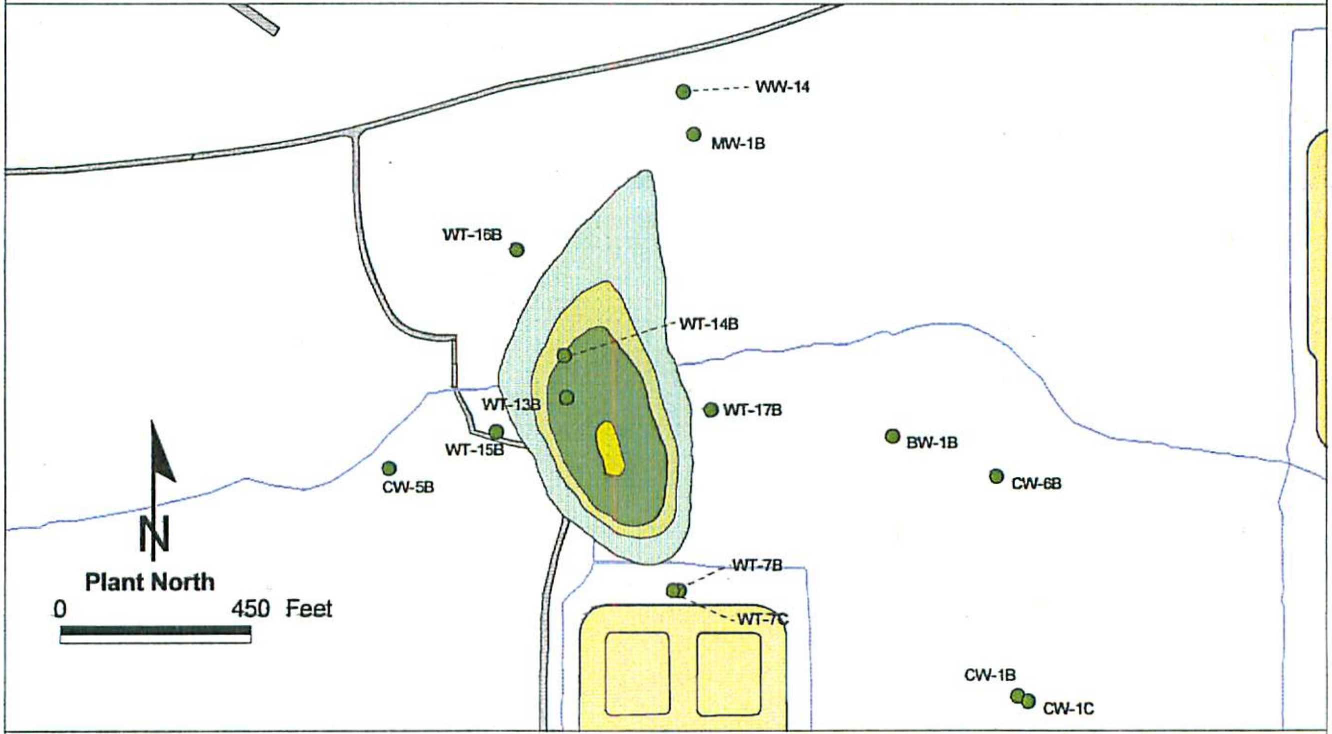
Figure 5-7

Nitrate Transport Model Scenario with Degradation -- Years 3 through 4

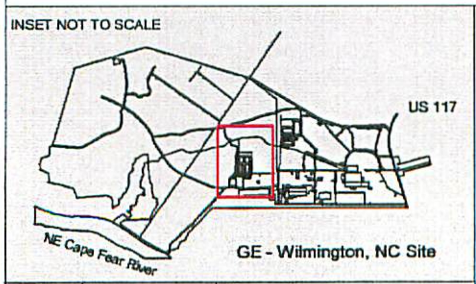
WT Area
GE - Wilmington, NC Site



Plume configuration 0 years after replacement of basin liners



Plume configuration 3 years after replacement of basin liners



RTI | Date: 11/16/99 | Map No.: 6448020005

Explanation

Simulated Nitrate
Concentration (mg/L as N)

▨ 10 - 50
▨ 50 - 100
▨ 100 - 499.9
▨ 500-1000
▨ >1000

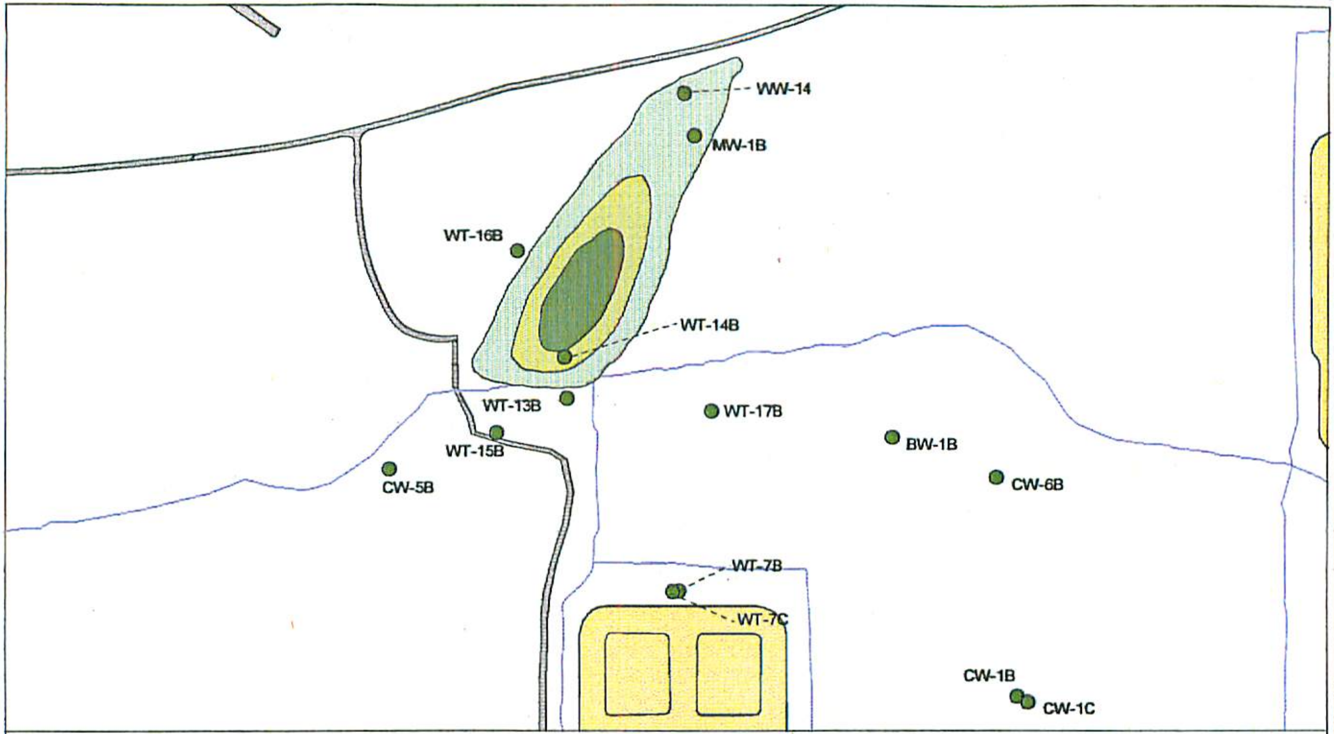
● WT-14B Principal aquifer well

╱╲ Surface water

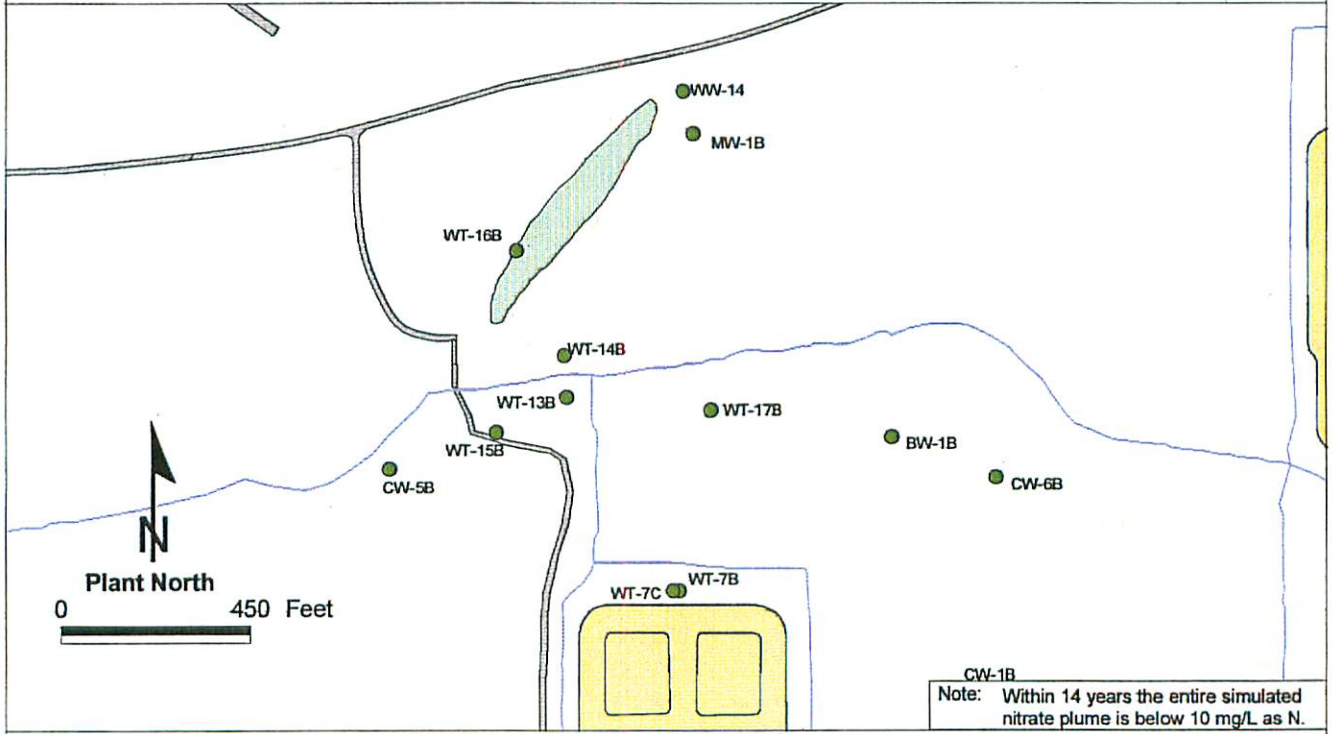
Figure 5-8

Nitrate Transport Model Scenario with No Degradation -- Years 0 through 3

WT Area
GE - Wilmington, NC Site



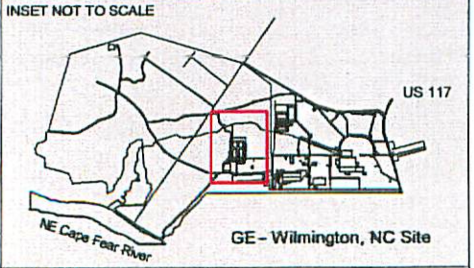
Plume configuration 6 years after replacement of basin liners



Note: Within 14 years the entire simulated nitrate plume is below 10 mg/L as N.

Plume configuration 12 years after replacement of basin liners

INSET NOT TO SCALE



RTI Date: 11/16/99 Map No.: 6448020005

Explanation

Simulated Nitrate Concentration (mg/L as N)

- ▨ 10 - 50
- ▨ 50 - 100
- ▨ 100 - 499.9
- ▨ 500-1000
- ▨ >1000

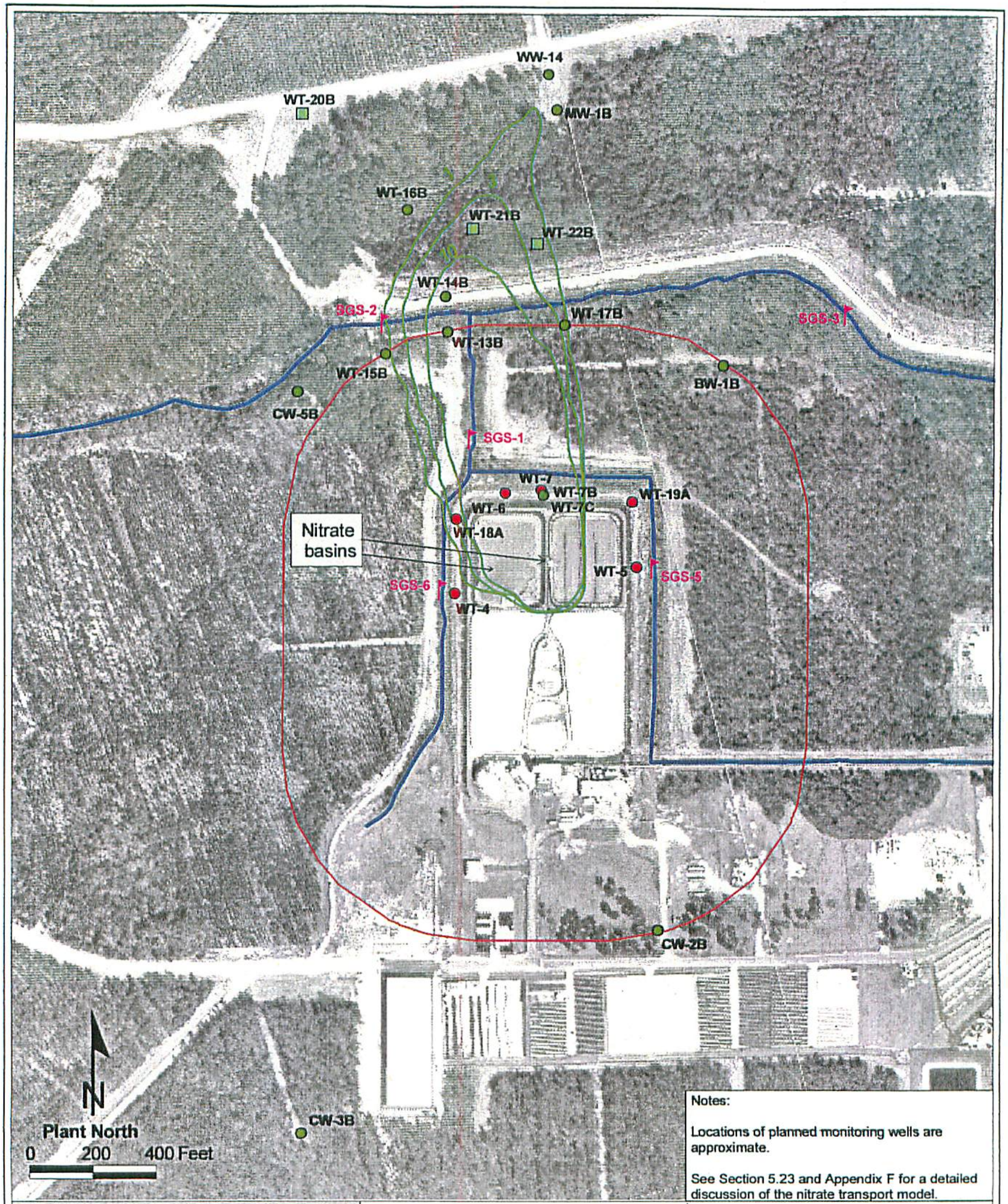
● WT-14B Principal aquifer well

╱╲ Surface water

Figure 5-9

Nitrate Transport Model Scenario with No Degradation -- Years 6 through 12

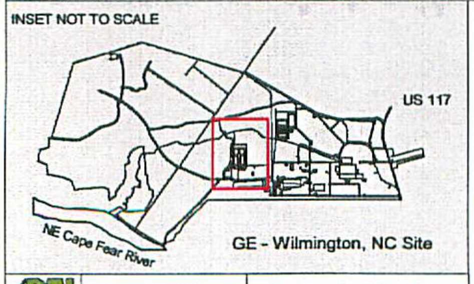
WT Area
GE - Wilmington, NC Site



Notes:

Locations of planned monitoring wells are approximate.

See Section 5.23 and Appendix F for a detailed discussion of the nitrate transport model.



Date: 11/18/99

Map No.: 6448020005

Explanation

- ● Existing surficial-aquifer well/piezometer
- ● Existing principal-aquifer well
- 🟩 Planned principal-aquifer well
- Stream-Gauging Station
- Extent of the modeled stable plume with degradation (in mg/L as N)
- ☐ 500-ft Compliance Boundary
- Drainage Ditch/Effluent Channel

Figure 7-1

Locations for Routine Monitoring of Nitrate in Groundwater and Surface Water

WT Area
GE - Wilmington, NC Site

TABLES

Table 1-1
Nitrate Liquid Characteristics

Analyte	Concentration (mg/L)			
	Average of Historical Analyses[a] (1989-1995)	1999 Area Investigation Analyses		
		West Basin	East Basin	
		March 1999	March 1999	August 1999
Chemicals of Concern				
Nitrate[b]	5,426	4,831	3,905	3,920
Ammonia[b]	753	308	351	210
Uranium (total)	0.31	0.472	3.31	0.189
Uranium (235)	NM	NM	0.00465	NM
Major Ions and Trace Metals				
Bicarbonate	NM	10.52	8.69	NM
Calcium	NM	5,640	4,630	NM
Carbonate	NM	ND	1.20	NM
Chloride	NM	ND	ND	NM
Chromium	0.05	NM	NM	NM
Copper	0.06	NM	NM	NM
Fluoride	4.19	4.3	2.88	NM
Magnesium	NM	26.7	31.9	NM
Nickel	0.20	NM	NM	NM
Potassium	NM	7.89	6.18	NM
Sodium	NM	8.84	11	NM
Sulfate	NM	ND	ND	NM
Rare-Earth Elements				
Dysprosium	NM	0.0037	0.00697	NM
Europium	NM	0.00155	ND	NM
Gadolinium	NM	6.89	0.422	NM
Hafnium	NM	0.0291	ND	NM
Miscellaneous				
Gross Alpha[c]	1,214	NM	NM	NM
Gross Beta[c]	1,224	NM	NM	NM
pH	NM	8.1	7.8	8.3

[a] Historical measurements were performed by GE on samples of the nitrate liquid being shipped to a paper manufacturer for beneficial utilization in their biological waste treatment process.

[b] Nitrate and ammonia results are reported in mg/L as nitrogen.

[c] Units for gross alpha and gross beta are pCi/L.

NM = Not measured
ND = Not detected

Table 2-1
Summary of WT Area Activities

Date(s)	Pertinent Field Location IDs (see Figure 1-2)	Activity Description	Activity Objective
1972	WT-1 through -7, and -9 (WT-4 reconstructed in 1984)	monitoring-well construction	monitor surficial-aquifer groundwater quality at perimeter of WT basins
1979	MW-2A, -3A, -4A MW-1B, -4B MW-4C	monitoring-well construction	monitor surficial-aquifer and principal-aquifer groundwater quality approximately 1000 feet from WT Facility
1990	CW-1A, -2A, -3A, -6A CW-1B, -2B, -3B, -4B, -5B, -6B CW-1C, -4C	monitoring-well construction	monitor surficial-aquifer and principal-aquifer groundwater quality at 500-foot compliance boundary around WT Facility
January 1998	east nitrate basin	reconnaissance and liner repair	identify and seal source of leakage observed at berm toe
August 1998	WTB-01 through -23	soil boring	characterize surficial-aquifer lithology, measure depth to semiconfining layer
August 1998	WTP-01, -02, -05 through -10, -012 through -017, and -019 through -023	piezometer construction	map water table
August 1998	SGS-1 through SGS-7	stream-gauge construction	evaluate relationship between surface-water and groundwater systems
September 1998	existing piezometers	groundwater sample collection	evaluate surficial-aquifer groundwater quality
December 1998	west nitrate basin	basin liner replacement	eliminate potential points of leakage
January-February 1999	WTB-24 through -30	soil boring, in-situ groundwater sampling	measure depth and thickness of semiconfining layer and characterize principal-aquifer groundwater quality
January-February 1999	WT-10A through -14A, WT-7B, -13B, and -14B	monitoring-well construction	enhance surficial- and principal-aquifer monitoring networks
February 1999	existing piezometers and monitoring wells	surface-water and groundwater sampling	comprehensively evaluate quality of surface-water and surficial- and principal-aquifer groundwater
February, April, and May 1999	WT-7B, -13B, -14B	groundwater sampling	confirm previous detections

Table 2-1 (continued)

Date(s)	Pertinent Field Location IDs (see Figure 1-2)	Activity Description	Activity Objective
March 1999	WTB-31 through -34	soil boring, in-situ groundwater sampling	characterize the vertical and lateral extent of nitrate in the principal-aquifer
March 1999	ditch well	site reconnaissance and groundwater sampling	inspect for potential nitrate-liquid release locations and further characterize surficial-aquifer groundwater quality
March 1999	12 monitoring wells throughout the WT area	slug testing	estimate principal-aquifer hydraulic conductivity
March 1999	nitrate basins and WT-7B	groundwater and nitrate liquid sampling	characterize nitrate liquid and compare to principal-aquifer groundwater quality
June 1999	WTB-35 through -38	soil boring, in-situ groundwater sampling	characterize the vertical and lateral extent of nitrate in the principal-aquifer, establish position for monitoring-well screens
June 10, 1999	not applicable	meeting at DENR Wilmington Regional Office	notify DENR Groundwater Section of identified groundwater contamination
June 21-22, 1999	east nitrate basin	hand augering	evaluate depth to water and lithology below basin before new liner is installed
June-July 1999	east nitrate basin	basin liner replacement and in-ground piping and sump removal	eliminate potential points of leakage
June-July 1999	WT-7C, -15B, -16B, -17B	monitoring-well construction	enhance principal-aquifer monitoring network
July-August 1999	selected existing monitoring locations	surface-water and groundwater sampling	commence routine monitoring program
October 1999	selected existing monitoring locations	surface-water and groundwater sampling	continue routine monitoring program
December 1999	WT-18A, WT-19A	monitoring-well construction	enhance surficial-aquifer monitoring network

Table 2-2
WT Area Monitoring-Well Construction Details

Well Number	GE Coordinates		Year Drilled	Well Diameter (inches)	Measurement Point Elevation* (ft msl)	Depth, feet below top of measurement point*			Pump Type
	North	East				Top of Screen	Bottom of Screen	Pump Intake	
Surficial-Aquifer Monitoring Wells									
CW-1A	4847	14161	1990	2	30.94	7.7	12.7	9	peristaltic
CW-2A	3912	13720	1990	2	42.25	13.8	23.8	22.7	peristaltic
CW-3A	3331	12711	1990	2	40.91	9.1	19.1	19.5	peristaltic
CW-6A	5379	14124	1990	2	30.72	8.8	13.8	12.2	peristaltic
MW-2A	4509.6	14606.1	1979	3	35.46	14.8	19.8	18.8	peristaltic
MW-3A	3388.6	13934.7	1979	3	41.40	14.8	19.8	18.5	peristaltic
MW-4A	3362.3	13233.5	1979	3	40.92	15.8	20.8	19.8	peristaltic
WT-1	4360.3	13398.7	1972	4	31.68	4.3	7.8	7.8	peristaltic
WT-2	4500.1	13157.7	1972	4	33.24	7.3	10.8	10.3	peristaltic
WT-3	4511.1	13655.5	1972	4	31.49	4.3	7.8	7.9	peristaltic
WT-4	4827.6	13155.3	1984	4	32.17	9.3	12.8	12.8	peristaltic
WT-5	4899.6	13658.6	1972	4	31.39	5.4	8.9	8.4	peristaltic
WT-6	5101.7	13295.4	1972	4	31.09	6.3	9.8	9.4	peristaltic
WT-7	5100.3	13410.4	1972	4	30.18	4.3	7.8	8.1	peristaltic
WT-9	4003.4	13595.5	1972	4	38.78	6.8	9.8	14.2	peristaltic
WT-10A	5232.6	12912.4	1999	2	31.44	6.7	8.6	7.8	peristaltic
WT-11A	5200.5	13737.3	1999	2	31.78	8.6	10.8	10.1	peristaltic
WT-12A	4761.6	13792.1	1999	2	33.63	9.8	14.8	13.0	bladder-T1200
WT-13A	5545.6	13142.6	1999	2	33.81	12.8	17.8	16.7	peristaltic
WT-14A	5642.8	13133.4	1999	2	24.45	6.8	8.8	8.4	peristaltic
WT-18A	5031	13157	1999	2	survey pending				peristaltic
WT-19A	5078	13646	1999	2	survey pending				peristaltic
Principal-Aquifer Monitoring Wells									
BW-1B	5457	13897	1994	2	30.42	27.6	37.6	27	bladder-T1500
CW-1B	4854	14192	1990	2	31.67	24.7	34.7	25	bladder-T1200
CW-1C	4841	14218	1990	2	31.92	39.8	49.8	40	bladder-T1200
CW-2B	3897	13720	1990	2	42.79	35.8	45.8	36	bladder-T1200
CW-3B	3337	12728	1990	2	41.89	33.8	43.8	34	bladder-T1200
CW-4B	4683	12621	1990	2	30.27	21.6	31.6	21	bladder-T1200
CW-4C	4666	12620	1990	2	30.04	42.8	52.8	43	bladder-T1200
CW-5B	5382	12716	1990	2	33.65	26.8	36.8	27	bladder-T1200
CW-6B	5362	14143	1990	2	29.98	27.8	34.8	28	bladder-T1200
MW-1B	6160.0	13431.9	1979	3	30.58	31.8	36.8	32.9	bladder-T1500
MW-4B	3371.8	13236.6	1979	3	40.82	32.8	37.8	32.0	bladder-T1200
MW-4C	3383.3	13239.6	1979	3	40.66	50.8	55.8	50.0	bladder-T1500
WT-7B	5097.1	13399.8	1999	2	30.45	23.3	32.8	23.1	bladder-T1200
WT-7C	5096.2	13385.3	1999	2	30.55	42.8	52.8	43.5	bladder-T1200
WT-13B	5546.7	13132.2	1999	2	33.96	29.3	38.8	29.0	bladder-T1200
WT-14B	5642.1	13125.7	1999	2	24.41	21.3	30.8	21.4	bladder-T1200
WT-15B	5466.6	12966.2	1999	2	32.09	25.8	35.8	26.2	bladder-T1200
WT-16B	5887.1	13014.4	1999	2	30.76	25.8	35.8	26.4	bladder-T1200
WT-17B	5518.0	13473.6	1999	2	31.82	25.8	35.8	26.2	bladder-T1200
WT-20B	construction pending			2	construction pending				bladder-T1200
WT-21B	construction pending			2	construction pending				bladder-T1200
WT-22B	construction pending			2	construction pending				bladder-T1200
WW-14**	6257	13408	1972	6	31.76	65.4	85.4	74	electric submersible

* Measurement points for monitoring wells are the tops of the 2-inch or 4-inch riser pipes.

** WW-14 is a plant process-water well.

ft msl = feet above mean sea level

Table 2-3
WT Area Surficial-Aquifer Piezometer Construction Details

Piezometer Number	GE Coordinates		Elevation of top of riser pipe (ft msl)	Depth (feet below top of riser pipe)	
	North	East		Top of screen	Bottom of screen
WTP-01	4102.9	12790.6	34.1	9.8	12.8
WTP-02	4671.5	12621.4	29.4	8.8	11.8
WTP-05	5142.5	13087.6	30.4	6.1	9.1
WTP-06	5456.5	13135.8	30.7	8.8	11.8
WTP-07	5339.7	12781.6	29.8	4.8	7.8
WTP-08	5448.6	13418.8	29.3	9.7	12.7
WTP-09	5265.3	13402.5	31.4	7.8	10.8
WTP-10	5052.1	13400.6	36.8	12.8	15.8
WTP-12	4034.7	13315.8	36.3	7.8	10.8
WTP-13	3995.2	13598.1	38.9	11.6	14.6
WTP-14	3879.1	13947.0	39.1	9.8	12.8
WTP-15	3970.8	13854.5	38.4	13.8	16.8
WTP-16	4102.7	13740.9	38.3	8.3	11.3
WTP-17	4209.3	13642.3	34.1	8.8	11.8
WTP-19	4391.5	13885.3	31.4	7.4	10.4
WTP-20	4097.3	14086.8	38.8	8.8	11.8
WTP-21	4985.5	13950.7	30.7	6.8	9.8
WTP-22	5372.3	14125.8	29.5	7.8	10.8
WTP-23	5472.6	13935.5	29.5	5.8	8.8

Note: Piezometer riser pipe and screens are all 0.5-inch inside diameter.
Piezometers were constructed in August 1998
ft msl = feet above mean sea level

Table 2-4
WT Area Soil-Boring Details

Boring Number	Month Drilled	GE Coordinates		Ground Surface Elevation (ft msl)	Depth (feet below ground surface) of In-Situ Groundwater Sampling Horizons	Identification of Well Constructed Inside or Situated Nearby Boring
		North	East			
WTB-24	January-99	4821.5	13156.3	29	31.5	WT-4
WTB-25	February-99	5227.0	12919.4	28	27	WT-10A
WTB-26	February-99	5097.1	13399.8	28	25	WT-7, -7B, -7C
WTB-27	January-99	5192.0	13742.2	29	28.5	WT-11A
WTB-28	January-99	4779.1	13797.5	31	33.5	WT-12A
WTB-29	January-99	5543.4	13116.5	31	35.25	WT-13A, -13B
WTB-30	January-99	5640.4	13109.9	22	25	WT-14A, -14B
WTB-31	March-99	5332	13273	29	31	none
WTB-32	March-99	6077	13008	31	13, 27, 31, 35	none
WTB-33	March-99	5097	13392	28	18, 21, 24, 29	WT-7, -7B, -7C
WTB-34	March-99	4383	13645	30	7, 22, 24.5	Ditch Well
WTB-35	June-99	5332	13273	30.1	15, 18, 22, 26, 29, 33	none
WTB-36	June-99	5485	12959	28.8	25, 30	WT-15B
WTB-37	June-99	5884	13018	27.69	None	WT-16B
WTB-38	June-99	5567	13458	28.59	25, 30, 35, 36.2	WT-17B

ft msl = feet above mean sea level

Table 3-1
Summary of WT Area Slug Test Results

Well	Top of Screen (MSL)	Bottom of Screen (MSL)	Middle of Screen (MSL)	Hvorslev Analysis Result (ft/day)	Bouwer-Rice Analysis Result (ft/day)
Wells screened deeper in the principal aquifer					
CW-1C	-7.8	-17.8	-12.8	7.7	6.3
CW-4C	-12.7	-22.7	-17.7	5.0	4.1
MW-1B	-1.2	-6.2	-3.7	12.1	7.8
MW-2B	-0.8	-5.8	-3.3	8.8	5.8
Geometric Mean (deeper wells)				**8.0**	**5.8**
Standard Deviation (deeper wells)				**2.9**	**1.5**
Wells screened shallower in the principal aquifer					
BW-1B	2.9	-7.2	-2.2	20.5	11.8
CW-1B	6.9	-3.1	1.9	21.3	13.5
CW-2B	7.0	-3.0	2.0	23.4	17.0
CW-4B	8.7	-1.3	3.7	26.0	16.4
CW-5B	6.9	-3.1	1.9	16.1	11.5
WT-13B	4.7	-4.8	0.0	28.3	16.6
WT-14B	3.2	-6.3	-1.6	34.2	19.6
WT-7B	7.2	-2.3	2.5	30.4	17.3
Geometric Mean (shallower wells)				**24.4**	**15.2**
Standard Deviation (shallower wells)				**5.9**	**2.9**
Geometric Mean (overall)				**16.8**	**11.1**
Standard Deviation (overall)				**9.6**	**5.3**

Note: This table presents results of pneumatic slug tests performed on March 17-18, 1999.
Appendix E provides details of the testing method and results.
MSL = Feet above mean sea level

Table 4-1
Analytical Results - Surface Water Samples

Station ID	Surface-Water Feature	Date Sampled	Fluoride (mg/L)	Ammonia (mg/L as N)	Nitrate (mg/L as N)	Total Uranium (mg/L)	Uranium Isotope 235 (mg/L)
			Oxford Laboratory			RTI Laboratory	
SGS-1 (mod)[a]	DD, downstream of WT	2/23/99	0.18	1.73	4.81	0.00065	NM
SGS-1		7/27/99	0.26	NM	NM	0.00131	NM
		8/9/99	NM	2.69	9.41	NM	NM
		10/25/99	0.57	1.46	6.04	0.00183	NM
SGS-2 (mod)[b]	EC, downstream of WT	2/23/99	0.26	0.62 *Ub*	2.03	0.0468	0.00101
SGS-2		7/27/99	0.45	NM	NM	0.0245	0.00095
		8/9/99	NM	0.64	1.17	NM	NM
		10/26/99	0.85	1.25	1.33	0.0326	0.000676
SGS-3	EC, upstream of WT	2/23/99	0.28	0.9 *Ub*	2.03	0.0669	0.00143
		7/27/99	0.28	NM	NM	0.0190	0.000551
		8/9/99	NM	1.56	0.10 ND	NM	NM
		10/26/99	0.25	0.21	0.93	0.0262	0.000435
SGS-5	DD, east of WT	2/23/99	0.21	0.20 ND	0.85	0.00183	NM
		7/27/99	0.27	NM	NM	0.00320	0.00015 ND
		8/9/99	NM	0.21 ND	0.26	NM	NM
		10/25/99	0.18	0.21 ND	0.44	0.00417	0.00015 ND
SGS-6	DD, west of WT	2/23/99	0.22	3.05	1.46	0.00071	NM
		7/27/99	0.54	NM	NM	0.00109	NM
		8/9/99	NM	5.16	0.39	NM	NM
		10/25/99	0.75	1.74	8.20	0.00080	NM

Notes

DD = Drainage ditch

EC = Effluent channel

0.24 ND = Parameter was not detected above the reporting limit of 0.24 mg/L

Ub = The sample result is qualitatively suspect because the analyte was detected in a field and/or laboratory blank at a similar level.

[a] The surface water sample was collected approximately 300 feet north of stream-gauging station SGS-1, shown in Figure 1-2. The sample was collected within the same north-flowing drainage ditch that contains SGS-1, just upstream of the confluence with the west-flowing effluent channel.

[b] The surface water sample was collected approximately 200 feet east of stream-gauging station SGS-2, shown in Figure 1-2. The sample was collected within the same west-flowing effluent channel that contains SGS-2, just downstream of the confluence with the north-flowing drainage ditch.

Table 4-2
Analytical Results - Groundwater Samples Collected from Surficial-Aquifer Monitoring Wells and Piezometers

Well ID	Date Sampled	Screen Top Elevation (ft msl)	Screen Bottom Elevation (ft msl)	Fluoride (mg/L)	Ammonia (mg/L as N)[b]	Nitrate (mg/L as N)[c]	Total Uranium (mg/L)	Uranium Isotope 235 (mg/L)
				Oxford Laboratory[a,b,c]			RTI Laboratory[a]	
CW-1A	2/19/99	25.4	20.4	0.10 ND	0.20 ND	0.34	0.000181	NM
				0.10 ND	0.20 ND	0.32	0.000152	NM
CW-2A	2/22/99	28.1	18.1	0.10 ND	0.20 ND	1.36	0.00015 ND	NM
CW-3A	2/18/99	29.9	19.9	0.10 ND	0.20 ND	3.13	0.00015 ND	NM
CW-6A	2/19/99	22.0	17.0	0.18	0.20 ND	2.49	0.00055	NM
MW-2A	2/17/99	20.0	15.0	0.10 ND	0.22 *Ub*	0.10 ND	0.00015 ND	NM
MW-3A	2/17/99	26.5	21.5	0.10 ND	0.20 ND	1.49	0.00015 ND	NM
MW-4A	2/17/99	25.6	20.6	0.10 ND	0.20 ND	2.79	0.00015 ND	NM
WT-1	2/23/99	26.2	22.7	7.15	18.0	74.3	0.122	0.00244
				7.05	18.4	75.2	0.150	0.00307
	7/27/99			6.2	NM	NM	0.140	0.00348
	10/26/99			3.85	NM	NM	0.196	0.00290
WT-2	2/23/99	26.5	23.0	0.10 ND	0.20 ND	1.33	0.00047	NM
	7/27/99			0.10 ND	NM	NM	0.00085	NM
	10/28/99			0.10 ND	NM	NM	0.00055	NM
WT-3	2/23/99	26.5	23.0	0.10 ND	2.99	0.10 ND	0.00046	NM
	7/27/99			0.10 ND	NM	NM	0.00088	NM
	10/28/99			0.10 ND	NM	NM	0.00060	NM
WT-4	1/29/99	21.2	17.7	1.00 ND [a]	0.76 [b]	1.34 [c]	0.02 ND [a]	NM
	2/23/99			0.10 ND	0.62 *Ub*	0.37	0.00056	NM
	7/27/99			0.10 ND	NM	NM	0.00046	NM
	8/10/99			NM	0.21 ND	0.34	NM	NM
	10/28/99			0.10 ND	0.21 ND	0.25	0.00036	NM
WT-5	2/23/99	25.8	22.3	0.10 ND	1.39	0.10 ND	0.00066	NM
	7/27/99			0.10 ND	NM	NM	0.00029	NM
	8/10/99			NM	1.77	0.10 ND	NM	NM
	10/28/99			0.10 ND	3.99	0.35	0.00018	NM
WT-6	2/23/99	25.3	21.8	0.10 ND	3.88	0.10 ND	0.00052	NM
	7/27/99			0.10 ND	NM	NM	0.00109	NM
	8/10/99			NM	6.15	0.10 ND	NM	NM
	10/28/99			0.10 ND	7.07	0.11	0.00081	NM
WT-7	2/1/99	24.8	21.3	1.00 ND [a]	0.40 [b]	3.68 [c]	0.02 ND [a]	NM
	2/23/99			0.16	0.28 *Ub*	2.06	0.00021	NM
	7/27/99			0.17	NM	NM	0.00030	NM
	8/10/99			NM	0.21 ND	0.10 ND	NM	NM
	10/28/99			0.16	0.21 ND	0.10 ND	0.00035	NM
WT-9	2/22/99	28.2	24.7	0.10 ND	0.20 ND	0.47	0.00015 ND	NM
WT-10A	2/18/99	25.1	23.1	0.23	0.20 ND	2.34	0.00036	NM
	7/28/99			0.10	NM	NM	0.00224	0.00015 ND
				0.11	NM	NM	0.00228	0.00015 ND
	10/28/99			0.15	NM	NM	0.00058	NM
WT-11A	2/19/99	23.7	21.7	0.14	0.20 ND	0.18	0.00026	NM
	7/28/99			0.10 ND	NM	NM	0.00047	NM
	10/25/99			0.13	NM	NM	0.00017	NM
WT-12A	2/18/99	23.5	18.5	0.22	0.27 *Ub*	0.10 ND	0.00015 ND	NM
	7/28/99			0.24	NM	NM	0.00032	NM
	10/25/99			0.25	NM	NM	0.00032	NM
				0.25	NM	NM	0.00029	NM
WT-13A	2/22/99	21.8	16.8	0.23	0.49 *Ub*	0.10 ND	0.00027	NM
WT-14A	2/22/99	17.8	15.8	0.10 ND	0.20 ND	0.10 ND	0.00020	NM
WTP-1	2/18/99	24.0	21.0	0.10 ND	0.20 ND	0.10 ND	0.00015 ND	NM
WTP-2	2/17/99	20.2	17.2	0.10 ND	0.22 *Ub*	0.10 ND	0.00015 ND	NM
WTP-5	2/18/99	24.4	21.4	0.11	0.20 ND	5.41	0.00041	NM
WTP-6	3/1/99	21.6	18.6	0.11	0.20 ND	0.10 ND	0.00138	NM
WTP-7	2/18/99	24.1	21.1	0.32	0.20 ND	1.65	0.00033	NM
WTP-8	2/22/99	19.1	16.1	0.10 ND	0.21 *Ub*	1.39	0.00033	NM
WTP-9	2/23/99	23.0	20.0	0.10 ND	0.20 ND	2.21	0.00154	NM
WTP-10	2/23/99	24.2	21.2	0.14	10.3	0.15	0.00054	NM
WTP-12	2/22/99	27.7	24.7	0.10 ND	1.53	0.10 ND	0.00015 ND	NM
WTP-13	2/22/99	27.0	24.0	0.10 ND	0.20 ND	0.75	0.00076	NM
WTP-14	2/23/99	28.9	25.9	0.10 ND	0.20 ND	1.53	0.00015 ND	NM
WTP-15	2/23/99	24.2	21.2	0.10 ND	0.20 ND	0.87	0.00099	NM
WTP-16	2/23/99	29.4	26.4	0.10 ND	0.97 *Ub*	0.10 ND	0.00015 ND	NM
WTP-17	2/23/99	24.5	21.5	0.10 ND	0.56 *Ub*	0.10 ND	0.00103	NM
WTP-19	2/18/99	23.3	20.3	0.10 ND	0.21 *Ub*	0.10	0.00015 ND	NM
WTP-20	2/23/99	29.4	26.4	0.10 ND	1.25	0.10 ND	0.00015 ND	NM
				0.10 ND	1.39	0.10 ND	0.00015 ND	NM
WTP-21	2/19/99	21.6	18.6	0.10 ND	0.21 *Ub*	0.10 ND	0.00015 ND	NM
WTP-22	2/19/99	21.9	18.9	0.18	0.21 *Ub*	1.62	0.00053	NM
WTP-23	2/19/99	23.0	20.0	0.12	0.20 ND	0.86	0.00119	NM
Ditch Well	3/24/99	25.4	25.4	7.41[a]	8.15[b]	11.08[c]	0.0398[a]	NM

Notes:

NM = Not measured

ft bls = feet below land surface

ft msl = feet above mean sea level

0.10 ND = Parameter was not detected above the reporting limit of 0.10 mg/L

Ub = The sample result is qualitatively suspect because the analyte was detected in a field and/or lab blank at a similar level.

[a] Fluoride and uranium analytical results were generated by the Chemet Laboratory, not Oxford Laboratory.

[b] Ammonia analytical result was generated by the Chemet Laboratory, not Oxford Laboratory, and was reported by the Chemet Laboratory in the units "ppm (mg/L) as NH_3". The concentration was converted to the units "mg/L as N" to be comparable to the data reported by Oxford Laboratory.

[c] Nitrate analytical result was generated by the Chemet Laboratory, not Oxford Laboratory, and was reported by the Chemet Laboratory in the units "ppm (mg/L) as NO_3". The concentration was converted to the units "mg/L as N" to be comparable to the data reported by Oxford Laboratory.

Table 4-3
Analytical Results - Groundwater Samples Collected from Principal-Aquifer Monitoring Wells

Well ID	Date Sampled	Screen Top Elevation (ft msl)	Screen Bottom Elevation (ft msl)	Fluoride (mg/L)	Ammonia (mg/L as N)[b]	Nitrate (mg/L as N)[c]	Total Uranium (mg/L)	Uranium Isotope 235 (mg/L)
				Oxford Laboratory[a,b,c]			RTI Laboratory[a]	
BW-1B	2/23/99	3.3	-6.7	0.14	0.20 ND	0.10 ND	0.00032	NM
	8/9/99			NM	0.21 ND	0.10 ND	NM	NM
	10/25/99			NM	0.28	0.10 ND	0.00396	0.00015 ND
CW-1B	2/18/99	5.9	-4.1	0.20	0.27 *Ub*	1.85	0.00016	NM
CW-1C	2/18/99	-8.1	-18.1	0.10 ND	0.20 ND	1.80	0.00027	NM
CW-2B	2/23/99	6.9	-3.1	0.17	0.20 ND	3.30	0.00182	NM
	8/11/99			NM	0.21 ND	3.23	NM	NM
	10/28/99			NM	0.21 ND	2.86	0.00246	0.00015 ND
CW-3B	2/18/99	7.7	-2.3	0.10 ND	0.20 ND	3.01	0.00016	NM
	8/11/99			NM	0.21 ND	3.62	NM	NM
	10/26/99			NM	0.21 ND	3.20	0.00015 ND	NM
CW-4B	2/17/99	8.8	-1.2	0.15	0.20 ND	0.32	0.00038	NM
CW-4C	2/17/99	-12.7	-22.7	0.10 ND	0.20 ND	0.10 ND	0.00015 ND	NM
CW-5B	2/18/99	6.9	-3.2	0.16	0.20 ND	4.21	0.00052	NM
	8/9/99			NM	0.21 ND	2.70	NM	NM
	10/28/99			NM	0.21 ND	3.10	0.00059	NM
CW-6B	2/19/99	1.7	-5.3	0.10 ND	0.20 ND	0.10 ND	0.00015 ND	NM
MW-1B	2/17/99	-1.4	-6.4	0.26	1.10	0.10 ND	0.00019	NM
	10/26/99			NM	2.99	0.10 ND	0.00030	NM
MW-4B	2/17/99	6.4	1.4	0.10 ND	0.20 ND	2.21	0.00075	NM
WT-7B	2/9/99	7.5	-2.5	1.0 ND [a]	NM	470 [c]	0.02 ND [a]	NM
	2/23/99			0.45	66.00	172	0.0288	0.00019
	3/11/99			1.0 ND [a]	87.9 [b]	208 [c]	0.0335	NM
	4/27/99			0.28	64.5	160	NM	NM
	5/20/99			0.36	54.5	163	NM	NM
	7/27/99			0.42	NM	NM	0.03210	0.00022
	8/10/99			NM	79.3	238	NM	NM
	10/26/99			0.39	68.6	201	0.0263	0.00015 ND
WT-7C	8/10/99	-12.2	-22.2	NM	8.34	0.10 ND	0.00252	0.00015 ND
	10/28/99			NM	8.05	0.10 ND	0.00117	NM
WT-13B	2/9/99	5.3	-4.7	1.0 ND [a]	NM	23.5 [c]	0.02 ND [a]	NM
	2/23/99			0.47	11.8	19.4	0.0276	0.00019
	4/27/99			0.55	12.9	20.1	NM	NM
	5/20/99			0.59	14.3	16.6	NM	NM
	8/9/99			NM	22.8	32.4	0.0340	0.00023
				NM	23.4	30.1	0.0341	0.00023
	10/26/99			NM	26.4	32.0	0.0405	0.00025
WT-14B	2/9/99	3.3	-6.8	1.0 ND [a]	NM	31.2 [c]	0.02 ND [a]	NM
	2/23/99			0.94	23.6	43.6	0.0230	0.00018
	4/27/99			1.09	27.3	34.1	NM	NM
	5/20/99			1.15	28.3	31.2	NM	NM
	8/9/99			NM	31.5	25.0	0.0522	0.00042
	10/26/99			NM	33.6	24.0	0.0424	0.00023
				NM	34.5	24.0	0.0432	0.00024
WT-15B	8/9/99	6.34	-3.66	NM	0.21ND	0.71	0.00197	NM
	10/26/99			NM	0.21ND	0.98	0.00108	NM
WT-16B	8/9/99	5.01	-4.99	NM	3.18	0.10 ND	0.00052	NM
	10/28/99			NM	2.03	0.10 ND	0.00048	NM
WT-17B	8/9/99	6.07	-3.93	NM	0.21 ND	0.10 ND	0.00015 ND	NM
	10/25/99			NM	0.35	0.10 ND	0.00015 ND	NM
WW-14	2/17/99	-33.6	-53.6	0.11	0.29 *Ub*	0.10 ND	0.00031	NM
	8/9/99			NM	0.21 ND	0.10 ND	NM	NM
	10/28/99			NM	0.21 ND	0.10 ND	0.00024	NM

Notes: NM = Not measured
ft bls = feet below land surface
ft msl = feet above mean sea level
0.10 ND = Parameter was not detected above the reporting limit of 0.10 mg/L

Ub = The sample result is qualitatively suspect because the analyte was detected in a field and/or laboratory blank at a similar level.

[a] Fluoride and uranium analytical results were generated by the Chemet Laboratory, not Oxford Laboratory.

[b] Ammonia analytical result was generated by the Chemet Laboratory, not Oxford Laboratory, and was reported by the Chemet Laboratory in the units "ppm (mg/L) as NH_3". The concentration was converted to the units "mg/L as N" to be comparable to the data reported by Oxford Laboratory.

[c] Nitrate analytical result was generated by the Chemet Laboratory, not Oxford Laboratory, and was reported by the Chemet Laboratory in the units "ppm (mg/L) as NO_3". The concentration was converted to the units "mg/L as N" to be comparable to the data reported by Oxford Laboratory.

Table 4-4
Analytical Results - In-Situ Groundwater Samples Collected from Principal-Aquifer Geoprobe Borings

Well ID	Date Sampled	Sample Depth (ft bls)	Sample Elevation (ft msl)	Filtration	Fluoride (mg/L)	Ammonia (mg/L as N)*	Nitrate (mg/L as N)*	Total Uranium (mg/L)
					Chemet Laboratory			
WTB-24	1/29/99	31.5	-2.5	Filtered	1.0 ND	1.11	3.63	0.02 ND
WTB-25	2/1/99	27	1	Filtered	1.0 ND	1.23	4.74	0.02 ND
WTB-26	2/1/99	25	3	Filtered	1.0 ND	108	239	0.02 ND
WTB-27	1/27/99	28.5	0.5	Filtered	1.0 ND	1.34	0.05 ND	0.02 ND
WTB-28	1/27/99	33.5	-2	Filtered	1.0 ND	3.43	0.75	0.02 ND
	1/26/99	33.5	-2	Unfiltered	1.0 ND	2.38	0.99	0.02 ND
WTB-29	1/28/99	35.3	-4.3	Filtered	1.22	28.5	208	0.02 ND
WTB-30	1/28/99	25	-3	Filtered	1.0 ND	11.8	114	0.02 ND
WTB-31	3/9/99	31	-2	Filtered	1.61	56.3	445	0.0216
	3/9/99	31	-2	Unfiltered	1.63	56.8	512	0.0366
WTB-32	3/10/99	13	18	Filtered	1.0 ND	1.33	0.06	0.02 ND
	3/11/99	27	4	Unfiltered	1.0 ND	8.5	0.07	0.02 ND
	3/11/99	27	4	Filtered	1.0 ND	8.5	0.05 ND	0.02 ND
	3/11/99	31	0	Unfiltered	1.0 ND	0.58	0.14	0.02 ND
	3/11/99	31	0	Filtered	1.0 ND	0.3 ND	0.05 ND	0.02 ND
	3/11/99	35	-4	Filtered	1.0 ND	0.3 ND	0.05 ND	0.02 ND
	3/11/99	35	-4	Unfiltered	1.0 ND	0.52	0.23	0.02 ND
WTB-33	3/15/99	18	10	Filtered	1.0 ND	81.3	18.1	0.02 ND
	3/15/99	18	10	Unfiltered	1.0 ND	79.9	18.9	0.0264
	3/15/99	21	7	Unfiltered	1.0 ND	40.1	99.1	0.02 ND
	3/15/99	24	4	Filtered	1.0 ND	15.0	61.9	0.02 ND
	3/15/99	29	-1	Filtered	1.0 ND	2.32	6.16	0.02 ND
WTB-34	3/16/99	7	23	Filtered	1.0 ND	1.73	0.09	0.02 ND
	3/16/99	22	8	Filtered	1.0 ND	2.20	0.05 ND	0.02 ND
	3/16/99	24.5	5.5	Filtered	1.0 ND	0.97	0.05 ND	0.02 ND
WTB-35	6/23/99	15	15.1	Filtered	NM	0.62	0.05 ND	NM
	6/23/99	18	12.1	Filtered	NM	0.81	0.05 ND	NM
	6/23/99	22	8.1	Filtered	NM	1.56	0.05 ND	NM
	6/23/99	26	4.1	Filtered	NM	169	312	NM
	6/23/99	29	1.1	Filtered	NM	134	264	NM
	6/23/99	33	-2.9	Filtered	NM	89	215	NM
WTB-36	6/17/99	25	3.8	Filtered	NM	0.48	0.05 ND	NM
	6/17/99	30	-1.2	Filtered	NM	0.33	4.24	NM
WTB-38	6/16/99	25	3.6	Filtered	NM	1.10	0.05 ND	NM
	6/16/99	30	-1.4	Filtered	NM	0.33	0.05 ND	NM
	6/16/99	35	-6.4	Filtered	NM	0.34	0.06	NM
	6/16/99	36.2	-7.6	Filtered	NM	0.3 ND	0.06	NM

Notes

0.2 ND = Parameter was not detected above the reporting limit of 0.2 mg/L
NM = Not measured
ft bls = feet below land surface
ft msl = feet above mean sea level

* The Chemet Laboratory reports ammonia and nitrate concentrations in the units "ppm (mg/L) as NO_3" and "ppm (mg/L) as NH_3," respectively. The ammonia and nitrate concentrations listed above in the units "mg/L as N" were calculated from the laboratory-reported concentrations.

Table 5-1
Field and Laboratory Analytical Results
Natural Attenuation Monitoring Parameters

Source	Date Sampled	$\delta^{15}N$ (‰)	$\delta^{18}O$ (‰)	pH	Dissolved Oxygen Content (mg/L)	Oxidation-Reduction Potential (mV)	Total Organic Carbon (mg/L)
Surface Water							
SGS-1	10/25/99	NM	NM	6.4	NM	NM	7.36
SGS-2	10/26/99	NM	NM	6.8	NM	NM	9.02
SGS-3	10/26/99	NM	NM	6.4	NM	NM	4.65
SGS-5	10/25/99	NM	NM	6.5	NM	NM	7.91
SGS-6	10/25/99	NM	NM	6.0	NM	NM	8.67
WT NE Basin	8/10/99	NM	NM	7.8	6.37	-20	6.20
Principal-Aquifer Groundwater							
BW-1B	8/9/99	NM	NM	5.2	1.40	95	NM
	10/25/99	NM	NM	5.1	0.90	115	1.95
CW-2B	8/11/99	NM	NM	4.3	7.65	260	0.50 ND
	9/28/99	5.32	9.75	NM	NM	NM	NM
	10/28/99	NM	NM	4.4	6.54	120	0.71
CW-3B	8/11/99	NM	NM	5.2	8.01	230	0.50 ND
	9/28/99	2.91	13.54	NM	NM	NM	NM
	10/26/99	NM	NM	4.4	7.07	245	0.50 ND
CW-5B	8/9/99	NM	NM	6.2	2.42	85	NM
	10/28/99	NM	NM	6.0	2.12	75	NM
	10/30/99	NM	NM	NM	NM	NM	1.40
MW-1B	10/26/99	NM	NM	4.3	1.73	65	3.13
WT-13B	8/9/99	NM	NM	4.1	1.30	300	1.00
	9/28/99	9.66	18.2	NM	NM	NM	NM
	10/26/99	NM	NM	3.5	2.32	285	1.88
WT-14B	8/9/99	NM	NM	4.2	1.70	285	1.21
	9/28/99	12.03	17.82	NM	NM	NM	NM
	10/26/99	NM	NM	4.0	2.44	265	2.09
WT-15B	8/9/99	NM	NM	5.8	1.03	175	NM
	10/26/99	NM	NM	4.9	3.16	165	0.91
WT-16B	8/9/99	NM	NM	5.4	1.50	105	NM
	10/28/99	NM	NM	5.4	2.78	85	2.99
WT-7B	8/10/99	NM	NM	3.9	1.23	285	1.28
	9/28/99	7.91	17.97	NM	NM	NM	NM
	10/26/99	NM	NM	3.4	3.00	180	0.98
WT-7C	8/10/99	NM	NM	8.1	1.71	35	NM
	10/28/99	NM	NM	7.9	1.65	-95	0.50 ND
WW-14	8/9/99	NM	NM	7.3	2.94	-70	NM
	10/28/99	NM	NM	6.9	1.72	-80	1.68
WT-17B	8/9/99	NM	NM	4.8	1.30	175	NM
	10/25/99	NM	NM	4.7	1.22	185	1.04
Principal-Aquifer Maximum:				**8.10**	**8.01**	**300**	**3.13**
Principal-Aquifer Minimum:				**3.40**	**0.90**	**-95**	**0.50 ND**
Principal-Aquifer Average:				**5.18**	**2.75**	**142.8**	**1.59**
Surficial-Aquifer Groundwater							
WT-1	10/26/99	NM	NM	5.9	NM	NM	NM
WT-10A	10/28/99	NM	NM	5.4	NM	NM	NM
WT-11A	10/25/99	NM	NM	5.0	NM	NM	NM
WT-12A	10/25/99	NM	NM	4.6	NM	NM	NM
WT-2	10/28/99	NM	NM	5.9	NM	NM	NM
WT-3	10/28/99	NM	NM	5.5	NM	-15	NM
WT-4	8/10/99	NM	NM	4.7	1.77	195	NM
	10/28/99	NM	NM	4.6	5.50	180	14.9
WT-5	8/10/99	NM	NM	4.7	1.12	120	NM
	10/28/99	NM	NM	5.2	4.23	65	3.55
WT-6	8/10/99	NM	NM	5.8	1.04	-15	NM
	10/28/99	NM	NM	6.2	4.07	-5	19.9
WT-7	8/10/99	NM	NM	6.1	2.67	30	NM
	10/28/99	NM	NM	6.3	3.92	115	NM
	10/31/99	NM	NM	NM	NM	NM	15.6
WTP-10	8/10/99	NM	NM	5.6	NM	50	NM
Surficial-Aquifer Maximum:				**6.30**	**5.50**	**195**	**19.90**
Surficial-Aquifer Minimum:				**4.60**	**1.04**	**-15**	**3.55**
Surficial-Aquifer Average:				**5.43**	**3.04**	**72.0**	**13.49**

<u>Notes:</u> $\delta^{15}N$ (‰) and $\delta^{18}O$ (‰) = the permil isotopic enrichments of nitrogen and oxygen, see Section 5.2.2

0.50 ND = Parameter was not detected above the reporting limit of 0.50 mg/L

NM = Not Measured

Table 5-2
Summary of Transport-Model Parameter Values

Parameter	Degradation Scenario	No-Degradation Scenario	Basis
Sorption Retardation Coefficient (R)	None	None	No sorption included; nitrate is a non-sorbing anion.
Longitudinal Dispersivity	3 feet	3 feet	Scale of the plume; calibration; (transport is relatively insensitive to dispersivity in this low range)
Longitudinal Dispersivity	0.3 feet	0.3 feet	
Biodegradation Rate (year $^{-1}$)	0.62 year $^{-1}$	None	Model calibration to measured concentrations; assumption of a stable, nonmigrating plume; well within ranges reported in literature (see Section 5.1.1).
Biodegradation Half Life (year)	1.12 year	None	

Note: Appendix F provides details about the development of the transport parameter estimates.

Table 5-3

Nitrogen to Ammonia Ratios
Principal-Aquifer Monitoring Wells

Well ID	Date Sampled	Nitrate (mg/L as N)	Ammonia (mg/L as N)	Nitrate/Ammonia Ratio	Approximate Down-gradient Distance (ft)
Nitrate Basins	3/11/99	3905	351	11.1	0
		4831	308	15.7	
	8/10/99	3920	210	18.7	
Nitrate-Basin average nitrate/ammonia ratio:				**15.2**	
WT-7B	2/23/99	172	66.0	2.61	150
	3/11/99	208	87.9	2.37	
	4/27/99	160	64.5	2.48	
	5/20/99	163	54.5	2.99	
	8/10/99	238	79.3	3.00	
	10/26/99	201	68.6	2.93	2 72
WT-7B average nitrate/ammonia ratio:				**2.73**	
WT-13B	2/23/99	19.4	11.8	1.64	650
	4/27/99	20.1	12.9	1.56	
	5/20/99	16.6	14.3	1.16	
	8/9/99	32.4	22.8	1.42	
		30.1	23.4	1.29	
	10/26/99	32.0	26.4	1.21	.58
WT-13B average nitrate/ammonia ratio:				**1.38**	
WT-14B	2/23/99	43.6	23.6	1.85	750
	4/27/99	34.1	27.3	1.25	
	5/20/99	31.2	28.3	1.10	
	8/9/99	25.0	31.5	0.79	
	10/26/99	24.0	33.6	0.71	
		24.0	34.5	0.70	.90
WT-14B average nitrate/ammonia ratio:				**1.07**	
WT-16B	8/9/99	0.10 ND	3.18	0.016	1050
	10/28/99	0.10 ND	2.03	0.025	
WT-16B average nitrate/ammonia ratio:				**0.021**	
MW-1B	2/17/99	0.10 ND	1.10	0.045	1400
	10/26/99	0.10 ND	2.99	0.017	
MW-1B average nitrate/ammonia ratio:				**0.031**	
WT-7C	8/10/99	0.10 ND	8.34	0.0060	150 (below the nitrate plume)
	10/28/99	0.10 ND	8.05	0.0062	
WT-7C average nitrate/ammonia ratio:				**0.0061**	

Notes

0.10 ND = Parameter was not detected above the reporting limit of 0.10 mg/L

One half of the reporting limit was used to calculate the nitrate/ammonia ratios when concentrations were not detected.

Appendix A

Field Sampling Plan for Monitoring of Nitrate in Waste Treatment Area Groundwater and Surface Water

RESEARCH TRIANGLE INSTITUTE

RTI Report No. 6448-020/002/01F

December 22, 1999

Field Sampling Plan for Monitoring of Nitrate in Waste Treatment Area Groundwater and Surface Water

Prepared for:

General Electric Company
Wilmington, North Carolina

Prepared by:

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List of Acronyms and Abbreviations

CaF_2	calcium fluoride
CEMQA	RTI Center for Environmental Measurements and Quality Assurance
COC	chain-of-custody
DENR	North Carolina Department of Environment and Natural Resources
DO	dissolved oxygen
EPA	U.S. Environmental Protection Agency
FSP	Field Sampling Plan
GE	General Electric
HNO_3	nitric acid
HPS	High Purity Standards
H_2SO_4	sulfuric acid
ICP-MS	inductively coupled plasma mass spectrometry
mg/L	milligrams per liter
mL	milliliter
MS	matrix spike
NIST	National Institute of Standards and Technology
ORP	oxidation/reduction potential
PE	performance evaluation
QA	quality assurance
QAPP	Quality Assurance Project Plan
QC	quality control
RTI	Research Triangle Institute
SM	*Standard Methods for the Evaluation of Water and Waste Water* (APHA, et al., 1992)
SNM	special nuclear material
SOP	standard operating procedure
TOC	total organic carbon
^{235}U	uranium isotope 235
VOA	volatile organic analysis
WT	Waste treatment

1.0 Introduction

This Field Sampling Plan (FSP) was prepared by the Research Triangle Institute (RTI) for monitoring of groundwater contamination identified near the Waste Treatment (WT) Facility of the General Electric (GE) site in Wilmington, North Carolina. The GE-Wilmington facility is located on US Highway 117 approximately 6 miles north of Wilmington and approximately 3 miles south of Castle Hayne, North Carolina.

This FSP is included as Appendix A of the *Waste Treatment Area Investigation Report* (RTI Report No. 6448-020/001/01F; December 22, 1999) and provides specific information on sampling locations, field methods and sampling procedures, sample handling and custody, quality control (QC) sampling, and field documentation. Standard operating procedures (SOPs) are included and referenced where appropriate. In addition to the quality assurance (QA)/QC measures presented in this FSP, this FSP adopts by reference the QA/QC procedures described in the Quality Assurance Project Plan (QAPP) (RTI Report No. 6448-020/003/01F; December 22, 1999) prepared for this monitoring program and included in the *Area Investigation Report* as Appendix B. The QAPP designates and documents the specifications and methods that will be employed to help establish technical accuracy and precision, statistical validity, and documentary evidence of generated data. The QAPP helps ensure that the data obtained for this project are of sufficient quality to meet the project-specific objectives.

The *Area Investigation Report* presents detailed information regarding site setting and history, geologic and hydrogeologic framework, nature and extent of the identified contamination, contaminant fate and transport, and potential receptors. As this FSP is designed as a self-standing document, pertinent *Area Investigation Report* excerpts regarding background information are included as appropriate in the next section.

2.0 Background Information

The WT Facility became operational in 1972. The base map shown in Figure 1 is an aerial photograph of the WT Facility taken in March 1996. There are four main elastomer-lined basins at the WT Facility. The two north basins contain a nitrate liquid. The two south basins hold a solid calcium-fluoride (CaF_2) material. As a voluntary measure, GE authorized RTI to conduct a hydrogeologic investigation of the WT area. In part, the investigation was designed to establish a baseline understanding of groundwater and surface-water quality before GE initiated removal of the CaF_2 from the two south basins. The preliminary findings of the assessment revealed a groundwater contaminant plume in the principal aquifer consisting of elevated concentrations of nitrate and ammonia. There is no evidence of impacts to groundwater quality from the CaF_2 basins. In response to these findings, GE authorized RTI to further investigate the nature and extent of the groundwater contamination. The findings of this area investigation are summarized below.

The suspected source of the nitrate and ammonia found in groundwater is leakage from one or both of the two nitrate-liquid basins. Based on the chemistry of the nitrate liquid, the chemicals of concern with respect to potential environmental contamination are nitrate, ammonia, and uranium exhibiting non-natural isotopic ratios. However, only nitrate and ammonia are evident in groundwater at levels that indicate an anthropogenic source. GE has addressed the suspected leakage by replacing the liners in both of these basins and by removing in-ground piping and a sump previously situated between the two basins.

2.1 Geologic and Hydrogeologic Framework

The geologic units in the region consist of undifferentiated surficial deposits overlying the Castle Hayne and Peedee Formations. The Castle Hayne Formation has not been identified beneath the GE property.

Two aquifers exist beneath the WT Facility: within the surficial deposits exists a surficial aquifer under water-table conditions; an underlying principal aquifer exists under semiconfined conditions within the Peedee Formation. In most areas, these two aquifers are separated by a lower-permeability semiconfining layer.

The surficial aquifer in the WT area consists of highly stratified, heterogeneous, unconsolidated sands, silts, and clays. Generally, the surficial aquifer ranges from 6 to 10 feet thick. Groundwater flow patterns are complex and strongly influenced by surface topography and surface water (drainage ditches and an effluent channel). Overall, surficial-aquifer groundwater in the WT area discharges to the drainage ditches and the effluent channel, thereby mixing with surface water and ultimately flowing to the Northeast Cape Fear River.

Based on the results of the WT area investigation activities, the low-permeability, clayey, semiconfining layer between the surficial and principal aquifers appears to be present across most of the WT area. Despite observed heterogeneities, the semiconfining layer appears to effectively separate the two aquifers in most areas as demonstrated by the differences in groundwater elevations between the surficial and principal aquifers.

The principal aquifer consists primarily of fine to medium sand. At depth, the sand becomes finer and glauconitic, and intermittent calcareous sandstone layers are encountered. Principal-aquifer groundwater flows generally to the north. Based on available data, groundwater flow in the principal aquifer across the WT area appears to be unaffected by the surface topography or positions of the drainage ditches.

A numerical model of groundwater flow in the principal aquifer was developed to enhance the understanding of groundwater flow patterns and to allow predictions of the future behavior of groundwater constituents. The model indicates a travel time of approximately 4 to 5 years for groundwater to flow from the north edge of the WT Facility to the leading edge of the nitrate plume (roughly 850 feet), which is consistent with the estimate calculated manually using Darcy's law. Once crossing the effluent channel, the groundwater is influenced by the capture zone of plant process-water wells and flows to the northeast toward these wells, which are not used for drinking-water supply.

2.2 Magnitude and Extent of Contamination

Several surface-water and groundwater sampling events were conducted during the recent area investigation, and a subsequent routine monitoring program has been implemented. These previously performed sampling events were conducted in general accordance with the procedures described in this FSP and the companion QAPP (Appendix B of the *Area Investigation Report*). Samples were analyzed for nitrate, ammonia, uranium, and fluoride. Tables 1 and 2 present the analytical results generated for surface-water and groundwater samples, respectively.

2.2.1 Surface-Water Quality. Although the suspected basin leakage has had a minor observable impact on surface-water quality, concentrations of the measured chemicals are currently below applicable regulatory levels.

2.2.2 Surficial-Aquifer Groundwater Quality. Contamination in the surficial aquifer is restricted to a small area south of GE's WT Facility building. This contamination is attributed to historical surface releases, has been reported previously to the North Carolina Department of Environment and Natural Resources (DENR) by GE, and is not attributed to the nitrate basin leakage. The objectives of the monitoring program presented in this FSP do not include monitoring of the surficial-aquifer contamination south of the WT facility building attributed to historical surface releases.

2.2.3 Principal-Aquifer Groundwater Quality. The approximate extent of the nitrate plume as described by a numerical transport model (model results closely match measured concentrations) is shown in Figure 1. Principal-aquifer groundwater nitrate concentrations exceeding the North Carolina groundwater standard of 10.0 mg/L (as nitrogen [N]) extend about 850 feet from the north edge of the east nitrate basin. Elevated levels of ammonia in principal-aquifer groundwater mostly mimic the nitrate pattern. However, ammonia has been detected slightly deeper and farther downgradient than has nitrate. Uranium detected in principal-aquifer groundwater north of the WT Facility demonstrates natural isotopic ratios. Therefore, these uranium detections are unrelated to the WT Facility CaF_2 and nitrate liquid. Although trace levels of fluoride have been detected in the principal aquifer in the area, none of the concentrations are above the 2.0 mg/L North Carolina groundwater standard.

Investigation results suggest that natural attenuation of the nitrate plume may be occurring. Using natural-attenuation parameters that are reasonable for this geochemical system, fate and transport modeling predicts that the position of the nitrate contamination plume would be stable and that the maximum nitrate concentrations in groundwater would fall below the North Carolina groundwater standard within approximately 5 years. Contaminant transport modeling predicts that, if no natural-attenuation processes were occurring, the ammonia and nitrate plumes would be contained by GE's active pumping-well network. In this highly conservative scenario, the maximum nitrate concentration in groundwater is predicted to fall below the North Carolina groundwater standard within approximately 14 years.

3.0 Objectives of the Sampling and Analysis Program

Consistent with the U.S. Environmental Protection Agency's (EPA's) directive on monitored natural attenuation (EPA, 1997), continuation of the recently initiated routine surface-water and groundwater monitoring program is intended to accomplish the following:

- Demonstrate that natural attenuation is occurring;
- Identify toxic transformation products, if applicable;
- Evaluate whether the plume is expanding in size;
- Detect new releases of contaminants that could impact the groundwater system being monitored;
- Demonstrate efficacy of institutional controls, if applicable;
- Detect changes in environmental conditions that may reduce the efficacy of the natural-attenuation processes; and
- Evaluate when North Carolina groundwater standards have been met.

Specifically, continuing the recently initiated routine surface-water and groundwater monitoring program enables GE and RTI to:

- Verify numerical flow-model predictions that principal-aquifer groundwater flow paths from the north WT basins terminate at wells WW-13 and WW-14 and that the only potential receptors of the identified principal-aquifer groundwater contamination would be workers that come in contact with the facility production water (not used as drinking water) pumped from these wells, should the contamination ever reach that far;

- Update the contaminant transport modeling predictions of future plume configurations by incorporating a more accurate understanding of the degree to which natural-attenuation processes are occurring;

- Monitor for any potential breakthrough of anthropogenic uranium from the nitrate liquid, which is currently observed to be effectively attenuated by the geologic materials situated between the basins and the principal aquifer; and

- Identify if an evaluation of additional remedial measures, such as in-situ enhancement of biological denitrification (e.g., soluble or insoluble carbon source injection), is warranted.

4.0 Sampling Plan Summary and Rationale

The monitoring activities described in this FSP involve routine collection of groundwater and surface-water samples in and around the WT Facility. Each sample will be analyzed for the three chemicals of concern with respect to potential environmental contamination from the nitrate liquid: nitrate, ammonia, and uranium exhibiting non-natural isotopic ratios. Initially, the sampling events described in this FSP will be conducted quarterly. At least once each year, additional analyses will be performed on samples to further evaluate for the occurrence of natural attenuation processes. In addition to collecting water samples from the selected locations described below, a comprehensive set of water-level measurements involving most of the wells, piezometers, and stream-gauging stations established in the WT area will be conducted each quarter. The following subsections present an overview of the sampling plan and the associated rationale.

4.1 Media Monitored and Sampling Locations

The media to be monitored include surface water in drainage ditches and the effluent channel and groundwater in the surficial aquifer and principal aquifer. Monitoring of these media will enable numerical flow-model predictions and contaminant fate and transport predictions to be verified and/or updated with respect to the nitrate and ammonia plumes, and provides monitoring for any potential breakthrough of uranium.

The sample locations are shown in Figure 1 and described in Section 5.0. Table 3 presents monitoring-well construction details for those wells included in this sampling program. The construction information shown on this table includes the depths of the well screens and sampling pumps indicating the vertical positions in the aquifer where groundwater will be collected from each well. These horizontal and vertical sampling locations allow for contaminants to be monitored at critical points along the migration pathway, such as:

- in surficial-aquifer and principal-aquifer groundwater near the suspected source (previous leakage area),
- in groundwater at various depths within the principal aquifer, and
- in surface water where surficial-aquifer groundwater water mixes with and becomes surface water.

In addition to sampling locations positioned along the migration pathway, monitoring wells to the side of and beneath the contaminant plumes are included in the monitoring program to verify that the plume is not expanding laterally or vertically.

4.2 Analyte List

Section 6.0 describes the laboratory analytical methods selected for this monitoring program. Samples will be collected for analysis of nitrate, ammonia, and total uranium. For those samples found to have total uranium concentrations above 0.002 milligrams per liter (mg/L), the individual uranium isotopes ^{234}U, ^{235}U, and ^{238}U also will be quantified to characterize natural versus anthropogenic uranium. As discussed in the *Area Investigation Report*, nitrate, ammonia, and uranium exhibiting non-natural isotopic rations are the only three chemicals of concern with respect to potential environmental contamination from the nitrate liquid. The following additional measurements will be performed at least once each year to interpret whether conditions are conducive for natural attenuation and/or to indicate whether natural-attenuation processes have been occurring:

- field measurement of oxidation/reduction potential (ORP),
- field measurement of dissolved oxygen (DO),
- field measurement of pH (performed every sampling event per Section 7.2.3 and SOPs 1, 2, and 12), and
- laboratory measurement of total organic carbon (TOC).

Natural-attenuation monitoring parameters may be added or deleted from this list, depending on the findings of the sampling and analysis activities.

The QAPP prepared for this monitoring program demonstrates that each of the selected laboratory analytical methods are appropriate considering the intended purpose of the data to be generated.

4.3 Field Methods and Procedures

The field methods and procedures presented in Section 7.0 have been selected to help ensure that field precision and accuracy meet project objectives, that the generated data are representative of the monitored systems, that the data are comparable between sampling events, and that the data are comparable to applicable regulatory standards and to previously collected data. The following summary of the prescribed field methods and procedures further describes the rationale of this monitoring program with respect to the intended use of the data and the data-quality indicators described above (precision, accuracy, representativeness, and comparability).

- The Standard Operating Procedures (SOPs) attached to this FSP will be followed. SOPs help ensure that field parameter measurement methodology and sample-collection protocol do not vary between sampling locations and from one sampling event to the next. The SOPs include procedures for calibrating field instruments and documenting the calibration adjustments. These records will help to identify a decrease in instrument performance that might warrant corrective action such as maintenance or replacement.

- Appropriate field equipment and procedures will be used to measure field parameters. Selection of high-quality instrumentation and techniques help ensure that accurate and precise field data are generated and that these data are comparable to previously collected data.

- Water samples will be collected using dedicated sampling equipment. Dedicated sampling equipment precludes the introduction of contaminants from one sampling location to the next due to improperly decontaminated sampling equipment. Use of dedicated equipment also enhances consistency in the manner in which samples are collected from one sampling event to the next. Dedicated bladder pumps are installed in the principal-aquifer monitoring wells. The dedicated tubing attached to each pump is lined with Teflon which will not adsorb and desorb contaminants. Similarly, peristaltic pumps are used to sample surficial-aquifer monitoring wells, and the tubing and foot valve used at each well is dedicated to the well. Surface-water samples are collected directly into new sample containers.

- New sample containers and disposable collection devices will be used. All samples submitted for laboratory analysis will be contained in new, clean-certified laboratory bottleware to preclude the introduction of contaminants from improperly decontaminated containers.

- Three types of field QC samples will be submitted to the analytical laboratory. In order to evaluate field and laboratory precision and accuracy, the following QC samples will be submitted to the analytical laboratory during each sampling event (a summary of the QC sampling plan is presented in Table 4):.

    - blind field duplicates,
    - blind field blanks, and
    - double-blind performance evaluation (PE) samples.

- Strict protocol regarding field documentation and sample handling, preservation, and custody will be followed. These procedures, detailed in Sections 7.3 and 7.5, help ensure that sample integrity is not compromised following collection and that defensible, complete documentation is maintained throughout the monitoring program.

5.0 Sampling Locations

Figure 1 is a map presenting the locations of 22 wells planned for routine groundwater sampling. Table 3 presents well-construction details for these wells. Six of the wells to be sampled are within the WT-facility fence and intercept surficial-aquifer groundwater before the groundwater discharges to the surrounding drainage ditches. Fourteen of the monitoring wells (identification numbers with the suffix "B") are completed in the upper portion of the principal aquifer. One monitoring well, WT-7C, is completed in a deeper portion of the principal aquifer. Well WW-14 is a plant process-water well that also is screened across the deeper portion of the principal aquifer. In addition to these 22 wells, the sampling plan includes collection of surface-water samples at five stream-gauging stations (SGS-1, -2, -3, -5, and -6).

6.0 Laboratory Analyses, Sample Containers, and Preservatives

Oxford Laboratories, Inc. (Oxford), of Wilmington, North Carolina, will analyze samples for nitrate using an automated cadmium reduction method (Standard Method [SM] 4500-NO_3-F) and for ammonia using a distillation/titration method (SM 4500-NH_3 -E) (APHA, et al., 1992). The maximum sample holding times for nitrate and ammonia analyses are 48 hours and 28 days, respectively.

The RTI Center for Environmental Measurements and Quality Assurance (CEMQA) Laboratory will analyze samples for total uranium by EPA Method 200.8 (EPA, 1994). This method employs inductively coupled plasma mass spectrometry (ICP-MS). The ICP-MS has the capability of measuring total uranium in a sample as well as the concentration of the individual uranium isotopes. The laboratory initially will measure the total uranium concentration of each sample. For those samples found to have a total uranium concentration of 0.002 mg/L or greater, the laboratory also will measure the concentration of three uranium isotopes (^{234}U, ^{235}U, and ^{238}U). The maximum sample holding time for uranium analyses is 6 months.

Table 4 is a sampling plan summary that lists the required sample containers and preservatives. At each sampling location, one 250-milliliter (mL) polyethylene bottle and one 500-mL polyethylene bottle will be filled and submitted to Oxford for nitrate and ammonia analyses, respectively, and a 250-mL polyethylene bottle will be filled and submitted to the RTI CEMQA laboratory for uranium analysis. At least once each year, an additional 250-mL polyethylene bottle will be filled and submitted to Oxford for TOC analysis. RTI purchases new certified-clean polyethylene bottles from scientific equipment vendors (e.g., Cole Parmer or VWR Scientific).

Samples to be analyzed for total and isotopic uranium must be preserved with nitric acid (HNO_3) and samples submitted for ammonia and TOC analyses must be preserved with sulfuric acid (H_2SO_4). RTI purchases certified reagent-grade HNO_3 and H_2SO_4 from a scientific equipment vendor and creates 50-percent dilutions using commercially available purified water. Immediately after each sample is collected for these analyses, the appropriate 50-percent solution is added to each sample bottle in the field using a dropper bottle dedicated for this use to lower the sample pH to less than 2.

Per our understanding of GE's internal screening protocol for Special Nuclear Material (SNM), sub-samples of the water collected from locations that, during the previous sampling event, showed a total uranium concentration exceeding 0.02 mg/L must be screened at GE's internal laboratory for total uranium concentrations before the other sample containers filled at those locations can be shipped to the respective laboratories listed above (see SOP 11). These samples are collected in 40-mL volatile organic analysis (VOA) vials provided by RTI (purchased from a scientific equipment vendor) and are preserved in the field with HNO_3.

Because PE samples are submitted to the laboratories blind, RTI provides the PE sample vendor, High Purity Standards (HPS) of Charleston, South Carolina, with containers to be filled with the PE samples. The PE vendor then fills these containers with the PE samples, adds required preservative, and sends the containers to the RTI Lead Field Geologist for inclusion in the sample delivery group.

7.0 Field Methods and Procedures

The collection of high-integrity environmental samples is important to the quality of the analytical data generated. Consequently, RTI has developed SOPs to provide standardized field procedures that will be employed for field data measurements and sample collection. Ten SOPs pertinent to this monitoring program (SOPs 1, 2, 3, 5, 6, 7, 8, 9, 11, and 12) are attached to this FSP. These SOPs are referenced throughout the following sections, which describe the field methods and procedures.

7.1 Preparation for Field Activities

In advance of each sampling event, the following preparatory activities will be conducted:

Time Before Sampling	Responsible Party	Preparatory Activity
5 weeks	Lead Field Geologist	Check supply of 40-mL glass VOA vials, 250-mL and 500-mL polyethylene bottles, nitric acid, sulfuric acid, and purified water. As needed, place orders with vendors for additional supplies.
		As needed, replenish supplies of chain-of-custody (COC) forms, sample bottle labels, custody seals, sample coolers, and packing/shipping materials.
4 weeks	QA Officer	Contact PE sample vendor (HPS) to indicate the timing of PE sample delivery.
		Prepare a letter to HPS specifying the requested concentration range and preservation requirements for the nitrate and uranium PE samples. Initiate a RTI purchase requisition, including the letter as an attachment.
3 weeks	Lead Field Geologist	Referring to Table 3, complete a Sample Sequence and Identifier Form (blank form attached to this FSP). Submit form to the Project Leader for review/approval.
	Project Leader	Review and modify/approve the completed Sample Sequence and Identifier Form.

Time Before Sampling	Responsible Party	Preparatory Activity
2 weeks	Lead Field Geologist	Ship empty sample containers for PE samples to HPS.
1 week	Lead Field Geologist	Contact RTI Laboratory, Oxford Laboratory, and GE Chemet Laboratory to inform of upcoming sampling event.
	QA Officer	Contact HPS to confirm they have received sample containers and associated paper work and to reconfirm sample shipment date.
within 1 week	Lead Field Geologist	Notify appropriate GE officials involved with the approval of SNM shipment (see attached SOP 11). Obtain GE shipping notice/release form.

7.2 Sample Collection and Field Measurement Procedures

This section describes the protocol for collecting groundwater and surface-water samples and the procedures for measuring field parameters.

7.2.1 Sampling Groundwater from Monitoring Wells. Each surficial-aquifer monitoring well included in this program is purged and sampled using a peristaltic pump as described in SOP 2. The three peristaltic pumps that may be used have maximum pumping rates that range from 0.2 to 0.4 liters per minute. The tubing used with the peristaltic pump is dedicated to each individual well. The principal-aquifer monitoring wells each are equipped with dedicated QED Well Wizard bladder pumps and Teflon-lined tubing. These pumps are used for purging and collecting water samples as described in SOP 1. Plant process-water well WW-14 is equipped with an electric submersible pump, and samples are collected from this well as described in SOP 12. After the prescribed volume of purge water has been removed from the well (see discussion below), pump operation will continue and groundwater samples will be collected into the required sample bottles shown in Table 4 and discussed in Section 6.0. Additional samples will be collected for GE's internal SNM screening protocol, as necessary (see SOP 11).

Before any water is removed from a monitoring well, the static depth to water will be measured using an electric water-level meter as described in SOP 3. These measurements will collectively be used to evaluate groundwater flow directions and to calculate the amount of water that must be purged from shallow monitoring wells before groundwater samples are collected.

The surficial-aquifer monitoring wells included in this monitoring program, listed in Table 3, have screens positioned where the water table at times is situated within the screened interval. The amount of water to be purged from these shallow wells before samples are collected will be equal to three times the volume of water present within the entire well. For each sampling event, the water-level measurement obtained by following the protocol presented in SOP 3 will be used in the following equation to calculate the amount of water to be purged from each shallow well:

$$PV_s = 3 \bullet \pi \bullet (SD \div 24)^2 \bullet (SB\text{-}WD) \bullet 28.32$$

where

PV_s = purge volume for shallow well, in liters

SD = screen diameter, in inches

SB = depth to bottom of screen (see Table 3), in feet below measurement point (typically top of well riser pipe)

WD = measured depth to water, in feet below measurement point.

The principal-aquifer monitoring wells included in this monitoring program, listed in Table 3, have a suffix "B," or "C," and these wells all have screens that are fully submerged beneath the water table. The amount of water to be purged from these deeper wells before samples are collected will be equal to three times the volume of water within the screened interval. Evacuation of three times the amount of water present in the entire well is not warranted because the purging rate will be sufficiently low to preclude drawing stagnant water from above the screen into the pump. As described in SOP 1, protocol involving use of electric water-level meters will be followed for ensuring that negligible drawdown is induced during purging of deeper wells. The amount of water to be purged from these wells is calculated by the following equation:

$$PV_d = 3 \bullet \pi \bullet (SD \div 24)^2 \bullet SL \bullet 28.32$$

where

PV_d = purge volume for deeper well, in liters

SD = screen diameter, in inches

SL = screen length, in feet.

All the principal-aquifer monitoring wells listed in Table 3 except MW-1B have nominal 10-foot long, 2-inch diameter screens. The calculated PV_d for these wells is 18.6 liters. With an 5-foot long, 3-inch diameter screen, the calculated PV_d for well MW-1B is 20.9 liters.

7.2.2 Surface-Water Sample Collection. Stream-gauging stations have been constructed at the five locations shown on Figure 1 where surface-water samples will be collected. Surface-water samples will be collected as described in SOP 5. The samples will be collected directly into the appropriate sample containers.

7.2.3 Field Parameter Measurements. After each of the groundwater sample containers required for laboratory analysis is filled, additional water will be produced to first rinse and then fill a polyethylene beaker. As required by SOPs 1, 2, and 12, measurements of the following field parameters will be performed during each sampling event on groundwater collected in the beaker:

- pH (see SOP 6),
- temperature (see SOP 7), and
- specific conductance (see SOP 7).

At least once each year, the following field parameters also will be measured:

- oxidation/reduction potential (see SOP 8) and
- dissolved oxygen (see SOP 9).

As mentioned in Section 4.0, each quarterly monitoring event will include a comprehensive set of water-level measurements involving most of the wells, piezometers, and stream-gauging stations established in the WT area. Groundwater level measurements will be performed according to the procedures described in SOP 3.

7.3 Sample Handling and Custody

After sample collection, sample containers destined for laboratory analysis will be wiped clean with a paper towel and identified by labeling the bottles with an indelible marker or by affixing waterproof adhesive labels. At a minimum, the containers will be marked with the sample identification number and the requested analyte(s) to be measured. As described in Section 6.0, samples to be analyzed for total uranium will be preserved with 50-percent HNO_3, and samples to be analyzed for ammonia and TOC will be preserved with 50-percent H_2SO_4. Except for the containers filled for uranium analysis, the containers will be placed in a clean cooler or on-site refrigerator and kept chilled until they are received by the laboratory. The cooler will contain sufficient coolant to chill the samples to less than 6 °C until they are transferred to the refrigerator or relinquished to the laboratory. The on-site refrigerator will be maintained approximately at 4 ± 2 °C. As currently required by the North Carolina Division of Water Quality Chemistry Laboratory, the samples will be stored and maintained between 0.1 and 4.4 °C while at the laboratory. Samples to be analyzed for uranium will be stored in clean coolers with no refrigerant until they are relinquished to the analytical laboratories.

For each sample to be submitted for laboratory analysis, an entry will be made on a chain-of-custody (COC) form. The information to be recorded includes the sampling date and time, sample identification number, requested analytes and methods, the number of containers per sample, and sampler's name. A separate COC form will be prepared for each of the involved laboratories. A blank copy of the COC form is attached to this FSP.

Sampling team members will maintain custody of the samples until they are relinquished to the on-site refrigerator or to laboratory personnel. The COC form will accompany the samples from the time of collection until they are received by the laboratory. Each party in possession of the samples (except the professional courier service) will sign the COC form signifying receipt. A copy of the original completed form will be provided by each laboratory along with the report of results.

It is important that coolers are packed properly to prevent breakage of sample containers and to maintain proper sample temperature, particularly when the samples are shipped via overnight courier service. Standardized procedures for packing sample coolers for shipment are presented in the attached SOP 11. As described in SOP 11, the COC form will be placed in a plastic bag and shipped with samples inside the cooler. Before coolers are relinquished to the professional courier service for shipment to the RTI CEMQA laboratory, custody seals will be placed on the cooler's lid after the samples and COC forms are packed. Custody seals provide assurance that the samples are not tampered with during transportation to the laboratory. Upon receipt, the laboratory will inspect the condition of the custody seals and report the information on the COC form. Samples for analyses other than uranium will be hand delivered to Oxford by a sampling team member, and so custody seals are not necessary for these sample coolers.

Upon receipt of the samples, the laboratories shall immediately notify the RTI Project Leader if conditions or problems are identified that require immediate resolution. Such conditions include container breakage, missing or improper COC forms, holding-time exceedances, missing or improper sample labeling, or frozen water samples.

As discussed in Section 6.0, GE has an internal screening protocol for SNM, and sub-samples of the water collected from locations that, during the previous quarter, showed a total uranium concentration exceeding 0.02 mg/L must be screened at GE's internal laboratory for total uranium concentrations before the other sample containers filled at those locations can be delivered to the respective laboratories. SOP 11 describes GE's SNM screening and shipment approval processes as they pertain to environmental samples.

7.4 Field Quality Control Samples

Table 4 is a sample collection plan summary for this monitoring program that lists the field QC samples required for this program. These field QC samples, described below, are part of the overall QA/QC program, the purpose of which is to produce data of known quality that satisfy the project objectives.

7.4.1 Field Duplicate Samples. Field duplicate samples will be collected and analyzed to evaluate sampling and analytical precision. Two duplicate-sample pairs will be collected each sampling event by filling approximately one third of each sample bottle at a time (sample containers will be filled directly without use of an intermediary container), alternating between each of the bottles that are required for the primary sample and the duplicate sample until all bottles are full. The duplicate samples will be analyzed by the same laboratory methods requested for the primary samples. An effort will be made to collect field duplicates at locations that are suspected to contain detectable concentrations of target analytes, but not such high concentrations that sample dilution would be required. The duplicate samples will be submitted to the laboratories blind.

7.4.2 Field Blanks. A field blank gives an indication of contamination induced from sample containers, preservatives, or the field environment (e.g., atmospheric vapors or wind-blown particulates). Commercially available purified water will be used for preparing the field blanks to be analyzed for nitrate, ammonia, and total uranium. Each field blank will be prepared in the field by pouring purified water from the bottle supplied by the laboratory into unused sample containers, adding the same chemical preservatives as used for the primary samples, and submitting the field blanks blind to the laboratories for analysis. Two field blanks will be collected each sampling event.

7.4.3 Performance Evaluation Samples. One set of PE samples will be submitted to the laboratories during each sampling event for analysis of nitrate and total uranium. The double-blind (i.e., the laboratories do not know which sample is the PE sample nor do they know the certified concentrations) PE samples will be prepared by HPS using National Institute of Standards and Technology (NIST) traceable standards. Sections 6.0 and 7.1 describe the procedures for providing this vendor with empty sample containers to be filled with the PE samples. The blind laboratory results will be evaluated against the original certificate of analyses during data validation (see QAPP, Appendix B of the *Area Investigation Report*) to evaluate laboratory accuracy.

7.4.4 Samples Selected for Matrix Spike Analyses. Matrix spike (MS) analyses are performed by each laboratory to evaluate the efficiency of the sample analytical procedure. For uranium analyses, at least one MS analysis will be performed with each analytical batch of 20 or fewer samples. For nitrate and ammonia analyses, at least one MS analysis will be performed with each analytical batch of 10 or fewer samples. The laboratory will perform these analyses using groundwater samples collected from the GE-Wilmington site.

The volumes of sample provided to the laboratory for uranium, nitrate, and ammonia analyses are sufficient for the initial analysis and a MS analysis. For nitrate and ammonia, Oxford selects which samples will be subjected to MS analyses. For uranium, the COC form will indicate which samples are to be used for MS analyses. These samples will be selected by field personnel considering historical concentrations so that spiked samples are likely to contain detectable uranium concentrations lower than the concentration of the spiking solution.

7.5 Field Documentation

This section further describes the sample identification numbering system and the various field documents that are required for this monitoring program.

7.5.1 Sample Numbering System. Monitoring well names and surface-water sampling location identifiers will not be listed on the sample bottle labels or the COC forms. Rather, each sample is identified by a sequential number. One sample identification number will be applied to all bottles filled at a particular sampling location for the required analytical methods. Each blind QC sample is listed as a separate entry on the COC form and, therefore, is assigned a separate sample identification number.

Attached to this FSP is a blank Sample Sequence and Identifier Form. Approximately 3 weeks before each sampling event, the RTI Lead Field Geologist will prepare this form for the RTI Project Leader review and approval (see Section 7.1). The form is filled out by listing each of the scheduled sampling locations, interspersing the blind QC samples as separate entries, and indicating which samples are selected for uranium MS analysis. The "COC Number" column is then filled out by identifying the highest number used in the previous sampling event and continuing the sequence by sequentially numbering on the form each line entry. The rest of the form is completed by checking off the analytical methods that apply to each sample. After approving the completed form, the Project Leader will provide a copy of the form to the RTI QA Officer and the RTI Database Specialist to facilitate data validation and proper data management, respectively.

7.5.2 Field Documents. In addition to the Sample Sequence and Identifier Form described in Section 7.5.1, the following field documents will be maintained throughout this monitoring program.

7.5.2.1 Field Instrument Calibration and Maintenance Records. SOPs 6 through 9, attached, describe the procedures for calibrating and operating the field analytical instruments to be used during this monitoring program. For each instrument, records of the calibration adjustments will be retained on a separate Field Instrument Calibration and Maintenance Record form (blank copy attached to this FSP). Maintaining these records will help to identify a decrease in instrument performance that might warrant corrective action such as repair by the manufacturer of obtaining a replacement instrument.

7.5.2.2 Field Sampling Record. Attached to this FSP is a blank Field Sampling Record form. A separate copy of this form will be completed for each sample collected to record information such as field parameter measurements, measured depth to water, purge rates and volume, etc. The RTI Lead Field Geologist will submit the completed forms to the RTI Project Leader who in turn will provide copies to the RTI Database Specialist and see that the originals are properly filed.

7.5.2.3 Sample Container Labels, Custody Seals, and Chain-of-Custody Forms. These labels, seals, and forms will be maintained as described in Section 7.3. The original copy of each COC form (blank copy attached to this FSP) is submitted along with the analytical report by the laboratory. The RTI Lead Field Geologist and the laboratory each retain copies of the COC form.

7.5.2.4 Field Notebook. As necessary, a daily field report can serve as a diary of field activities and can be used to record pertinent data that are not included on the other forms described above. Daily field reports are maintained by sampling team leaders in bound field notebooks. Recorded information may include general site conditions, daily weather, equipment used, equipment problems, handling and disposal of investigative-derived waste, and other relevant information, including any deviations from this FSP.

7.6 Health & Safety Issues and Handling and Disposal of Investigative-Derived Waste

Implementation of this FSP will result in the contact and handling of surface water and groundwater that may contain low-level contamination as described in Section 2.2 and listed in Tables 1 and 2. The known levels of these contaminants do not warrant personal protective equipment other than gloves (latex, nitrile, or vinyl). In addition, safety glasses may be appropriate when sampling wells WT-7B, WT-13B, and WT-14B.

Purge water extracted from monitoring wells in the WT area will either be discharged to the ground surface (if contaminants of interest are below threshold levels/NC groundwater standards) or containerized and transferred to the central GE facility process lagoon for treatment. Table 5 summarizes the expected disposition of purge water based on existing analytical data. No other investigative-derived waste is anticipated other than standard trash that will be disposed in appropriate solid-waste receptacles at the GE facility.

8.0 References

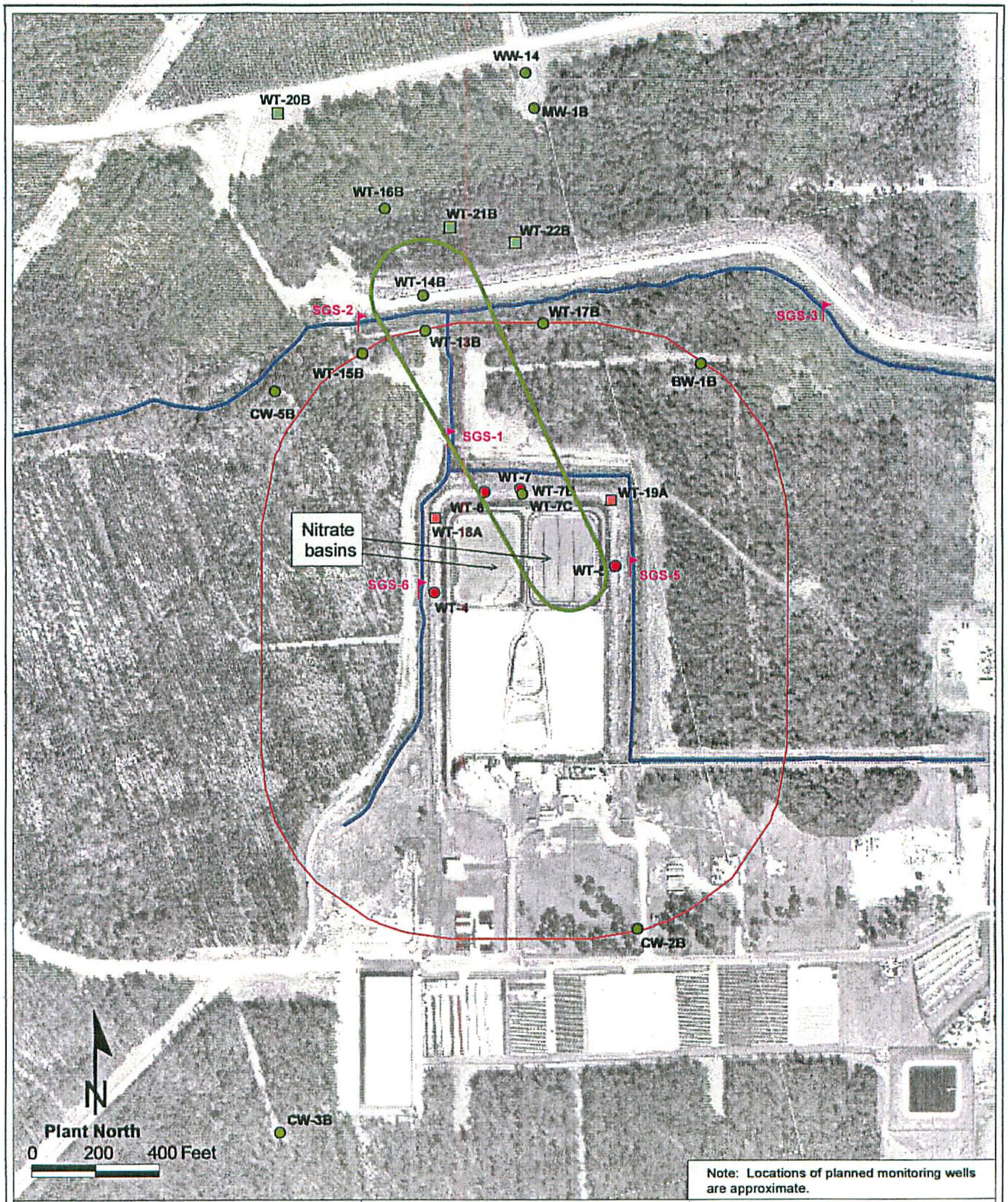
American Public Health Associations, American Water Works Association, and Water Pollution Control Federation (APHA, et al.). 1992. *Standard Methods for the Evaluation of Water and Waste Water.* 18th edition.

Research Triangle Institute (RTI). 1999. *Waste Treatment Area Investigation Report.* RTI Report 6448-020/001/01F.

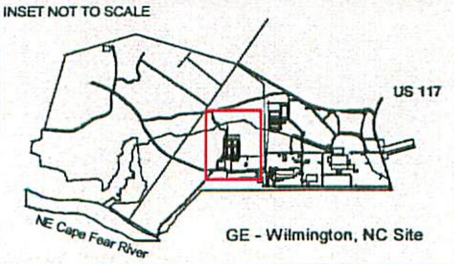
U.S. Environmental Protection Agency (EPA). 1994. *Methods for Determination of Metals in Environmental Samples.* Supplement I. EMSL-CI. EPA/600/R-94/111.

U.S. Environmental Protection Agency (EPA). 1997. *Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites.* Office of Solid Waste and Emergency Response Directive No. 9200.4-17.

FIGURE



Note: Locations of planned monitoring wells are approximate.



RTI Date: 12/8/99 Map No.: 6448020006

Explanation

- ● Existing surficial-aquifer well/piezometer
- 🟥 Planned surficial-aquifer well
- ● Existing principal-aquifer well
- 🟩 Planned principal-aquifer well
- Stream-gauging station
- Inferred extent of nitrate > 10 mg/L (as N)
- ☐ 500-ft Compliance Boundary
- Drainage Ditch/Effluent Channel

Figure 1

Locations for Routine Monitoring of Nitrate in Groundwater and Surface Water

WT Area
GE - Wilmington, NC Site

TABLES

Table 1
Analytical Results - Surface Water Samples

Station ID	Surface-Water Feature	Date Sampled	Fluoride (mg/L)	Ammonia (mg/L as N)	Nitrate (mg/L as N)	Total Uranium (mg/L)	Uranium Isotope 235 (mg/L)
			Oxford Laboratory			RTI Laboratory	
SGS-1 (mod)[a]	DD, downstream of WT	2/23/99	0.18	1.73	4.81	0.00065	NM
SGS-1		7/27/99	0.26	NM	NM	0.00131	NM
		8/9/99	NM	2.69	9.41	NM	NM
		10/25/99	0.57	1.46	6.04	0.00183	NM
SGS-2 (mod)[b]	EC, downstream of WT	2/23/99	0.26	0.62 *Ub*	2.03	0.0468	0.00101
SGS-2		7/27/99	0.45	NM	NM	0.0245	0.00095
		8/9/99	NM	0.64	1.17	NM	NM
		10/26/99	0.85	1.25	1.33	0.0326	0.000676
SGS-3	EC, upstream of WT	2/23/99	0.28	0.9 *Ub*	2.03	0.0669	0.00143
		7/27/99	0.28	NM	NM	0.0190	0.000551
		8/9/99	NM	1.56	0.10 ND	NM	NM
		10/26/99	0.25	0.21	0.93	0.0262	0.000435
SGS-5	DD, east of WT	2/23/99	0.21	0.20 ND	0.85	0.00183	NM
		7/27/99	0.27	NM	NM	0.00320	0.00015 ND
		8/9/99	NM	0.21 ND	0.26	NM	NM
		10/25/99	0.18	0.21 ND	0.44	0.00417	0.00015 ND
SGS-6	DD, west of WT	2/23/99	0.22	3.05	1.46	0.00071	NM
		7/27/99	0.54	NM	NM	0.00109	NM
		8/9/99	NM	5.16	0.39	NM	NM
		10/25/99	0.75	1.74	8.20	0.00080	NM

Notes

DD = Drainage ditch

EC = Effluent channel

0.24 ND = Parameter was not detected above the reporting limit of 0.24 mg/L

Ub = The sample result is qualitatively suspect because the analyte was detected in a field and/or laboratory blank at a similar level.

[a] The surface water sample was collected approximately 300 feet north of stream-gauging station SGS-1, shown in Figure 1. The sample was collected within the same north-flowing drainage ditch that contains SGS-1, just upstream of the confluence with the west-flowing effluent channel.

[b] The surface water sample was collected approximately 200 feet east of stream-gauging station SGS-2, shown in Figure 1. The sample was collected within the same west-flowing effluent channel that contains SGS-2, just downstream of the confluence with the north-flowing drainage ditch.

Table 2
Analytical Results - Groundwater Samples

Well ID	Date Sampled	Screen Top Elevation (ft msl)	Screen Bottom Elevation (ft msl)	Fluoride (mg/L)	Ammonia (mg/L as N) [b]	Nitrate (mg/L as N) [c]	Total Uranium (mg/L)	Uranium Isotope 235 (mg/L)
				Oxford Laboratory [a, b, c]			RTI Laboratory [a]	
Surficial-Aquifer Monitoring Wells								
WT-4	1/29/99	21.2	17.7	1.00 ND [a]	0.76 [b]	1.34 [c]	0.02 ND [a]	NM
	2/23/99			0.10 ND	0.62 *Ub*	0.37	0.00056	NM
	7/27/99			0.10 ND	NM	NM	0.00046	NM
	8/10/99			NM	0.21 ND	0.34	NM	NM
	10/28/99			0.10 ND	0.21 ND	0.25	0.00036	NM
WT-5	2/23/99	25.8	22.3	0.10 ND	1.39	0.10 ND	0.00066	NM
	7/27/99			0.10 ND	NM	NM	0.00029	NM
	8/10/99			NM	1.77	0.10 ND	NM	NM
	10/28/99			0.10 ND	3.99	0.35	0.00018	NM
WT-6	2/23/99	25.3	21.8	0.10 ND	3.88	0.10 ND	0.00052	NM
	7/27/99			0.10 ND	NM	NM	0.00109	NM
	8/10/99			NM	6.15	0.10 ND	NM	NM
	10/28/99			0.10 ND	7.07	0.11	0.00081	NM
WT-7	2/1/99	24.8	21.3	1.00 ND [a]	0.40 [b]	3.68 [c]	0.02 ND [a]	NM
	2/23/99			0.16	0.28 *Ub*	2.06	0.00021	NM
	7/27/99			0.17	NM	NM	0.00030	NM
	8/10/99			NM	0.21 ND	0.10 ND	NM	NM
	10/28/99			0.16	0.21 ND	0.10 ND	0.00035	NM
Principal-Aquifer Monitoring Wells								
BW-1B	2/23/99	3.3	-6.7	0.14	0.20 ND	0.10 ND	0.00032	NM
	8/9/99			NM	0.21 ND	0.10 ND	NM	NM
	10/25/99			NM	0.28	0.10 ND	0.00396	0.00015 ND
CW-2B	2/23/99	6.9	-3.1	0.17	0.20 ND	3.30	0.00182	NM
	8/11/99			NM	0.21 ND	3.23	NM	NM
	10/26/99			NM	0.21 ND	2.86	0.00246	0.00015 ND
CW-3B	2/18/99	7.7	-2.3	0.10 ND	0.20 ND	3.01	0.00016	NM
	8/11/99			NM	0.21 ND	3.62	NM	NM
	10/26/99			NM	0.21 ND	3.20	0.00015 ND	NM
CW-5B	2/18/99	6.9	-3.2	0.16	0.20 ND	4.21	0.00052	NM
	8/9/99			NM	0.21 ND	2.70	NM	NM
	10/28/99			NM	0.21 ND	3.10	0.00059	NM
MW-1B	2/17/99	-1.4	-6.4	0.26	1.10	0.10 ND	0.00019	NM
	10/26/99			NM	2.99	0.10 ND	0.00030	NM
WT-7B	2/9/99	7.5	-2.5	1.0 ND [a]	NM	470 [c]	0.02 ND [a]	NM
	2/23/99			0.45	66.00	172	0.0288	0.00019
	3/11/99			1.0 ND [a]	87.9 [b]	208 [c]	0.0335	NM
	4/27/99			0.28	64.5	160	NM	NM
	5/20/99			0.36	54.5	163	NM	NM
	7/27/99			0.42	NM	NM	0.03210	0.00022
	8/10/99			NM	79.3	238	NM	NM
	10/26/99			0.39	68.6	201	0.0263	0.00015 ND
WT-7C	8/10/99	-12.2	-22.2	NM	8.34	0.10 ND	0.00252	0.00015 ND
	10/28/99			NM	8.05	0.10 ND	0.00117	NM
WT-13B	2/9/99	5.3	-4.7	1.0 ND [a]	NM	23.5 [c]	0.02 ND [a]	NM
	2/23/99			0.47	11.8	19.4	0.0276	0.00019
	4/27/99			0.55	12.9	20.1	NM	NM
	5/20/99			0.59	14.3	16.6	NM	NM
	8/9/99			NM	22.8	32.4	0.0340	0.00023
				NM	23.4	30.1	0.0341	0.00023
	10/28/99			NM	26.4	32.0	0.0405	0.00025
WT-14B	2/9/99	3.3	-6.8	1.0 ND [a]	NM	31.2 [c]	0.02 ND [a]	NM
	2/23/99			0.94	23.6	43.6	0.0230	0.00018
	4/27/99			1.09	27.3	34.1	NM	NM
	5/20/99			1.15	28.3	31.2	NM	NM
	8/9/99			NM	31.5	25.0	0.0522	0.00042
	10/26/99			NM	33.6	24.0	0.0424	0.00023
				NM	34.5	24.0	0.0432	0.00024
WT-15B	8/9/99	6.34	-3.66	NM	0.21ND	0.71	0.00197	NM
	10/26/99			NM	0.21ND	0.98	0.00108	NM
WT-16B	8/9/99	5.01	-4.99	NM	3.18	0.10 ND	0.00052	NM
	10/28/99			NM	2.03	0.10 ND	0.00048	NM
WT-17B	8/9/99	6.07	-3.93	NM	0.21 ND	0.10 ND	0.00015 ND	NM
	10/25/99			NM	0.35	0.10 ND	0.00015 ND	NM
Principal-Aquifer Plant Process-Water Well								
WW-14	2/17/99	-33.6	-53.6	0.11	0.29 *Ub*	0.10 ND	0.00031	NM
	8/9/99			NM	0.21 ND	0.10 ND	NM	NM
	10/28/99			NM	0.21 ND	0.10 ND	0.00024	NM

Notes:
NM = Not measured
ft bls = feet below land surface
ft msl = feet above mean sea level
0.10 ND = Parameter was not detected above the reporting limit of 0.10 mg/L

Ub = The sample result is qualitatively suspect because the analyte was detected in a field and/or laboratory blank at a similar level.

[a] Fluoride and uranium analytical results were generated by the Chemet Laboratory, not Oxford Laboratory.

[b] Ammonia analytical result was generated by the Chemet Laboratory, not Oxford Laboratory, and was reported by the Chemet Laboratory in the units "ppm (mg/L) as NH_3". The concentration was converted to the units "mg/L as N" to be comparable to the data reported by Oxford Laboratory.

[c] Nitrate analytical result was generated by the Chemet Laboratory, not Oxford Laboratory, and was reported by the Chemet Laboratory in the units "ppm (mg/L) as NO_3". The concentration was converted to the units "mg/L as N" to be comparable to the data reported by Oxford Laboratory.

Table 3
WT Area Monitoring-Well Construction Details

Well Number	GE Coordinates*		Year Drilled	Well Diameter (inches)	Measurement Point Elevation* (ft msl)	Depth, feet below top of measurement point**			Pump Type
	North	East				Top of Screen	Bottom of Screen	Pump Intake	
Surficial-Aquifer Monitoring Wells									
WT-4	4827.6	13155.3	1984	4	32.17	9.3	12.8	12.8	peristaltic
WT-5	4899.6	13658.6	1972	4	31.39	5.4	8.9	8.4	peristaltic
WT-6	5101.7	13295.4	1972	4	31.09	6.3	9.8	9.4	peristaltic
WT-7	5100.3	13410.4	1972	4	30.18	4.3	7.8	8.1	peristaltic
WT-18A	5031	13157	1999	2	survey pending				peristaltic
WT-19A	5078	13646	1999	2	survey pending				peristaltic
Principal-Aquifer Monitoring Wells									
BW-1B	5457	13897	1994	2	30.42	27.6	37.6	27	bladder-T1500
CW-2B	3897	13720	1990	2	42.79	35.8	45.8	36	bladder-T1200
CW-3B	3337	12728	1990	2	41.89	33.8	43.8	34	bladder-T1200
CW-5B	5382	12716	1990	2	33.65	26.8	36.8	27	bladder-T1200
MW-1B	6160.0	13431.9	1979	3	30.58	31.8	36.8	32.9	bladder-T1500
WT-7B	5097.1	13399.8	1999	2	30.45	23.3	32.8	23.1	bladder-T1200
WT-7C	5096.2	13385.3	1999	2	30.55	42.8	52.8	43.5	bladder-T1200
WT-13B	5546.7	13132.2	1999	2	33.96	29.3	38.8	29.0	bladder-T1200
WT-14B	5642.1	13125.7	1999	2	24.41	21.3	30.8	21.4	bladder-T1200
WT-15B	5466.6	12966.2	1999	2	32.09	25.8	35.8	26.2	bladder-T1200
WT-16B	5887.1	13014.4	1999	2	30.76	25.8	35.8	26.4	bladder-T1200
WT-17B	5518.0	13473.6	1999	2	31.82	25.8	35.8	26.2	bladder-T1200
WT-20B	construction pending			2	construction pending				bladder-T1200
WT-21B	construction pending			2	construction pending				bladder-T1200
WT-22B	construction pending			2	construction pending				bladder-T1200
Principal-Aquifer Plant Process-Water Well									
WW-14	6257	13408	1972	6	31.76	65.4	85.4	74	electric submersible

* Well locations shown on Figure 1.

** Measurement points for monitoring wells are the tops of the 2-inch or 4-inch riser pipes.

ft msl = feet above mean sea level

Table 4
Sampling Plan Summary

Laboratory/ Location	Analyte	Analytical Method	Maximum Holding Time	Container	Preserv-ative	Sampling Event	Number of Samples Each Sampling Event			
							Primary Sample	Duplicate[a]	Field Blank[a]	PE Sample[b]
RTI CEMQA Laboratory/ Research Triangle Park, NC	Total and Isotopic[d] Uranium	EPA 200.8	6 months	1 polyethylene bottle, 250 mL	HNO_3 ($pH < 2$)	quarterly	27 (1 per location shown on Figure 1)	2	2	1
Oxford Laboratories, Inc./ Wilmington, NC	Nitrate	SM 4500-NO_3-F	48 hours	1 polyethylene bottle, 250 mL	chilled[c]	quarterly	27 (1 per location shown on Figure 1)	2	2	1
	Ammonia	SM 4500-NH_3-E	28 days	1 polyethylene bottle, 500 mL	H_2SO_4 ($ph < 2$), chilled[c]		27 (1 per location shown on Figure 1)	2	2	0
	Total Organic Carbon	SM 5310-C	28 days	1 polyethylene bottle, 250 mL	H_2SO_4 ($ph < 2$), chilled[c]	annual	22 (1 per monitoring well listed in Table 3)	1	0	0

[a] Quality-control sample submitted blind to analytical laboratories.

[b] Performance evaluation sample submitted as a double-blind sample to the analyical laboratories.

[c] Upon sample collection, samples will be maintained in a cooler with sufficient coolant to chill the samples to less than 6 °C until received by the analytical laboratory. While in the laboratory, samples will be stored and maintained between 0.1 and 4.4 °C as required by the North Carolina Division of Water Quality Chemistry Laboratory.

[d] Isotopic analysis is performed only on samples with a total uranium concentration of 0.002 mg/L or above.

Table 5
Disposition of Water Purged from Monitoring Wells

Sampling Location ID	Disposition of Purge Water	
	Ground Surface	Containerized and Transferred to the GE - Wilmington Facility Process Lagoon
Surficial-Aquifer Monitoring Wells		
WT-4	✓	
WT-5	✓	
WT-6	✓	
WT-7	✓	
WT-18A	✓	
WT-19A	✓	
Principal-Aquifer Monitoring Wells		
BW-1B	✓	
CW-2B	✓	
CW-3B	✓	
CW-5B	✓	
MW-1B	✓	
WT-7B		✓
WT-7C	✓	
WT-13B		✓
WT-14B		✓
WT-15B	✓	
WT-16B	✓	
WT-17B	✓	
WT-20B	✓	
WT-21B	✓	
WT-22B	✓	
WW-14*	✓	

* Well WW-14 is a plant process-water well. Except for water produced from the sampling port while filling sample containers, purge water is plumbed for use as plant process water.

ATTACHMENTS

Blank Field Forms

Standard Operating Procedures

Blank Field Forms

RTI Chain-of-Custody Form
Sample Sequence and Identifier Form
Field Instrument Calibration and Maintenance Record
Field Sampling Record

Page ____ of ____

RESEARCH TRIANGLE INSTITUTE
Geosciences Department
P.O. Box 12194
Research Triangle Park, NC 27709

CHAIN-OF-CUSTODY

Client:	Project Name:	Project No:
Address:	RTI Contact:	
Laboratory:	Phone No.:	Fax No.:
Address:	Sampler:	Sampler:

Requested Turnaround Time:	☐ Normal ________	☐ Rush ________	☐ Emergency (ASAP)

Source(s)	Custody Number(s)*	Date/Time Sampled	Sequence	Matrix**	Container/Vial Information				Method(s) Requested	Comments
					Type	Volume	No. of Containers	Preservation		

* Multiple container samples (spares) should be analyzed in alphabetical order.

** GW=Groundwater, SW=Surface Water, SO=Soil

Transfer No.	Relinquished by:	Date/Time:	Received by:	Date/Time:	Comments:
1					
2					

LABORATORY RECEIVING INFORMATION:

Received By:______________ Date:________ Time:________ Cooler Temp.: _____°C or _____ °F

RTI

	Intitials	Date
Prepared By:		
Approved By:		

Sample Sequence and Identifier Form

Planned Sampling Dates: ______________________

		Laboratory:	**RTI**	**Oxford**		
		Analytes:	**Total Uranium**[b]	**Nitrate**	**Ammonia**	**Total Organic Carbon**
		Containers/ Preservatives:	**(1) 250 mL polyethylene / HNO_3 (pH < 2)**	**(1) 250 mL polyethylene / chilled** [c]	**(1) 500 mL polyethylene / H_2SO_4 (pH < 2); chilled** [c]	**(1) 250 mL polyethylene / H_2SO_4 (pH < 2); chilled** [c]
Sampling Location ID	**COC Number**	**QC Type**[a]	**Required Analyses (enter "✓")**			

Notes

[a] QC Types

P = primary sample
D = duplicate sample
MS = primary sample selected for uranium matrix spike analysis
FB = field blank
PE = performance evaluation sample

[b] Enter "**Chemet**" if the sample is to be analyzed for uranium and the previous sampling event total uranium concentration exceeded 0.02 mg/L. Then, have a sub-sample screened at GE's Chemet Laboratory for total uranium before the other sample containers are shipped offsite (see SOP 11) for uranium and/or other analyses.

[c] Upon sample collection, samples will be maintained in a cooler with sufficient coolant to chill the samples to less than 6 °C until received by the analytical laboratory. While in the laboratory, samples will be stored and maintained between 0.1 and 4.4 °C as required by the North Carolina Division of Water Quality Chemistry Laboratory.

GE-Wilmington
RTI Project No. 6448

Instrument: ____________________
Model: ____________________

Field Instrument Calibration and Maintenance Record

Date of Calibration or Maintenance	Calibration/ Maintenance Performed By	Calibration Solutions Used and Expiration Date	Maintenance Activies (e.g. battery or membrane replacement)	Comments

RTI

RTI Project No. ________ **RTI**

Field Sampling Record (Aqueous Samples)

Sample Sequence No.__________ **Well/Location I.D.** ______________
Sample Custody No. ______________ **Date Sampled:**______________

Sample Type/Source *(check one):*
Water Well _____ Monitoring Well _____ Rinse Blank _____
Surface Water____ Field Blank _____ Blind Duplicate _____

Water Wells:
Initial Pump Status: ON OFF* Purge Start: ___:___ Water Level________
Purge/Discharge Rate: _____ gpm Purge Stop: ___:___ (ft below measuring point)

* Allow pump to discharge (purge) 15 min. prior to sampling. Return switch to original position.

Monitoring Wells:
Static Water Level: _______ ft.** Well Depth______ft**
Pump Intake Depth:_______ ft**(if applicable) Sample Depth: _____ ft.**

Purging Information:
Calculated Purge Volume: _______ L
Actual Purge Volume : _______ L
Purge Rate: _____ L/min.
** below measuring point (top of casing)

Purge Method:______________________________
Purge Start: ___:___ Purge Stop: ___:___
Purge Water Level : _______ ft.**
Purge-Water Appearance______________________

Water Quality Measurements:

pH:	_____	Sp. Cond:	_____	Temp:	____	DO	_____	Fe(II)	____	ORP	____	Time	__:__
(units)	_____	(µmhos/cm)	_____	(°C)	____	(ppm)	_____	(ppm)	____	(mV)	____		__:__

Field Equipment (Rinse) Blanks:

Rinsate Collected From:______________________________
Comments/Observations:______________________________

Field Blanks:

Sampling Location:______________________________
Conditions:______________________________

Blind Duplicate Samples:

Sample No. Duplicated:________________ Well I.D. ______________
Conditions:______________________________

Sample Collection Information

Sampled by:____________/____________
Sampling Method________________
Sample Time: ___:___
Sampling Rate: __________ L/min.

Sample	________	Preservative:__________	Lab:__________	Comments: __________
Custody	________	Preservative:__________	Lab:__________	Comments: __________
Nos:	________	Preservative:__________	Lab:__________	Comments: __________

Disposition of Purge Water:______________________________

SOP Exceptions:______________________________

Standard Operating Procedures

SOP 1	Groundwater Sample Collection Using a Bladder Pump
SOP 2	Groundwater Sample Collection Using a Peristaltic Pump and Bailer
SOP 3	Field Measurement of Depth to Water in Wells using an Electric Water-Level Meter
SOP 5	Surface-Water Sample Collection
SOP 6	Field Measurement of Water-Sample Hydrogen Ion Concentration (pH)
SOP 7	Field Measurement of Water-Sample Temperature-Compensated Conductance (Specific Conductance)
SOP 8	Field Measurement of Water-Sample Oxidation/Reduction Potential
SOP 9	Field Measurement of Water-Sample Dissolved Oxygen Content
SOP 11	Screening Samples and Packing Sample Coolers for Shipping
SOP 12	Groundwater Sample Collection from High-Capacity Wells

STANDARD OPERATING PROCEDURE 1, Revision 2.0
Groundwater Sample Collection Using a Bladder Pump

1.0 SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure (SOP) is to delineate protocols for purging monitoring wells and collecting groundwater samples using a QED 1200- or 1500-series dedicated bladder pump, a QED Well Wizard Model 400 controller, and a portable gasoline-powered air compressor. These protocols are designed to facilitate purging of stagnant water from the wells and collecting groundwater samples that are representative of actual aquifer conditions.

This SOP is intended to eliminate sample-collection conditions that could compromise sample quality. These compromising conditions include excessive discharge pressure (particularly when sampling for volatile organic compounds [VOCs]), turbidity, unstable field parameters, atmospheric introduction of compressor exhaust, excessive drawdown of the water column, purging wells to dryness, inadequate sample cooling conditions, and cross contamination between wells.

For monitoring wells with screens placed across or just below the water table, the bladder-pump intake usually is set in the lower portion of the well screen. The purge volume is three times the volume of the water column standing in the well (refer to Section 3.2).

For monitoring wells with screens substantially submerged beneath the static water level, the bladder-pump intake usually is set approximately 1 foot below the top of the well screen. The purge volume for these wells is three times the volume of water in the screened section of the well. For these wells, the purge rate is reduced to minimize the total drawdown in the well (<1.5 feet) and therefore the introduction of standing water from above the screen.

The "3X well volume" is an arbitrary value specified by regulatory agencies (including the NC Department of Environment and Natural Resources [DENR]) attempting to ensure that samples of groundwater representative of actual conditions are collected, not stagnant water present in the well.

Project-specific Field Sampling Plans (FSPs) may prescribe collection of groundwater samples for a variety of laboratory analyses, and may prescribe collection of both unfiltered and filtered groundwater samples. If filtered samples are to be collected, a disposable high-capacity 0.45-micron filter capsule will be attached to the discharge line with decontaminated fittings/clamp, and the effluent from the filter capsule will be collected.

For most projects, the FSP will require collection of samples in the anticipated order of increasing contamination. To avoid impairment of samples from inappropriate preservatives or excessive turbidity, samples should be collected in the following order: 1) unfiltered and unpreserved inorganic analyte samples, 2) unfiltered and preserved VOC samples, 3) unfiltered and preserved inorganic analyte samples, and 4) filtered and preserved inorganic analyte samples.

2.0 EQUIPMENT AND MATERIALS

a. QED 1200- or 1500-series bladder pump (dedicated to each well and outfitted with appropriate well cap and tubing)
b. Well Wizard Model 400 controller with air-supply line to pump
c. Gasoline-powered air compressor with discharge line (filled with fuel away from the sampling site while wearing nitrile gloves and appropriate personal protective equipment before sampling is initiated)
d. Insulated cooler with frozen ice packs
e. Polyethylene graduated cylinders (2,000 mL and 100 mL) and beakers (100 mL and 500 mL)
f. Disposable nitrile gloves
g. Sample containers and preservatives specified in the project-specific FSP
h. pH meter and conductivity/temperature meter (see SOPs 6 and 7) plus any other groundwater field parameter meters designated in the FSP
i. Resealable sample bags
j. Stopwatch
k. Purified water in spray bottle
l. Disposable laboratory wipes (e.g., Kimwipes)

m. Well-construction information (if not previously entered on Field Sampling Record form)
n. Field Sampling Record forms, project notebook, waterproof-ink pens
o. Calculator
p. Electric water-level indicator (see SOP 3)
q. Purge-water collection buckets with lids
r. Teflon-lined discharge tubing and elbow connectors (typically dedicated to each well and stored in locked well protective casing)
s. Trash bags

Note: If filtered samples are to be collected: dedicated flexible (Tygon or C-Flex) tubing, decontaminated polyethylene connectors, hose clamps, and new filter capsules will be necessary.

3.0 PROCEDURE

3.1 Unlock well and measure static water level from surveyed measurement point (typically the top of the well riser pipe, sometimes identified by a survey mark) with an electrical water level indicator (see SOP 3). Record water level on the Field Sampling Record form. Clean water-level probe with purified water and laboratory wipes.

3.2 Calculate minimum required purge volume as follows:

3.2.1 For monitoring wells with screens placed across or just below the water table, the amount of water to be purged is equal to three times the volume of water present within the entire well, calculated as follows:

$$PV_s = 3 \bullet \pi \bullet (SD \div 24)^2 \bullet (SB\text{-}WD) \bullet 28.32$$

where

PV_s = purge volume for shallow well, in liters
SD = screen diameter, in inches
SB = depth to bottom of screen, in feet below measurement point (typically top of well riser pipe)
WD = measured depth to water, in feet below measurement point.

3.2.2 For monitoring wells with screens substantially submerged beneath the static water level, the amount of water to be purged is equal to three times the volume of water within the screened interval of the well, calculated as follows:

$$Pv_d = 3 \bullet \pi \bullet (SD \div 24)^2 \bullet SL \bullet 28.32$$

where
Pv_d = purge volume for deeper well, in liters
SD = screen diameter, in inches
SL = screen length, in feet.

3.3 Position compressor with exhaust directed away from sampling point and connect air-supply line from the air compressor to the pump controller.

3.4 Connect air-supply line from the controller to the bladder pump connector fitting on the well cap.

3.5 Attach Teflon-lined discharge tubing and elbow to pump discharge line.

3.6 Set refill and discharge cycles initially to 15 seconds each and set pump drive air throttle to approximately 25 to 40 PSIG, depending on depth of well.

3.7 Start compressor engine, start controller, and adjust bladder-pump discharge/recharge cycles until the end of the discharge cycle coincides with the end of the water flow (i.e., fully discharged) and the volume of water discharged from the pump is approximately equal to the pump capacity as measured with the graduated cylinders (i.e., fully refilled). Note: The T1500 pump capacity is approximately 2.7 L and the T1200 pump capacity is approximately 1.2 L. At first discharge, record start time on Field Sampling Record form. Contain or disperse purge water as specified in the FSP.

3.8 Measure water level in well on first discharge cycle and periodically throughout purge interval to measure total drawdown. In consideration of the project-specific FSP, the pump setting, and the well yield, adjust the flow rate discharge with air throttle, regulator, or length of discharge time (e.g., a total drawdown of less than 1.5 feet must be maintained for wells with submerged screens).

3.9 Measure pump single discharge volume on second discharge cycle to calculate purge rate. Example: 1.4 L in 30-second refill and discharge cycle = 2.8 L per minute purge rate. Divide the purge volume (L) by the purge rate (L/min) to calculate purge time (min). Record purge rate and total purge time on the Field Sampling Record form.

3.10 Near the end of the purge cycle prior to sample collection, don nitrile gloves and collect purge-water sample in beaker for measurement of pH, specific conductance, and temperature (see SOPs 6 and 7) plus any other field-parameter measurements specified in the project-specific FSP. Record measurements on Field Sampling Record form. Clean instrument probes and beakers used for field-parameter measurement with a purified-water spray after each reading. Note: Minimize purge water aeration in beaker when measuring dissolved oxygen and oxidation/reduction potential (ORP) by reducing the discharge pressure and allowing the beaker to fill from the bottom.

3.11 After field parameters have been measured, increase controller discharge time and reduce discharge pressure. Collect samples at low-flow rate (as close to 0.1 L/min as possible for VOCs, and approximately 0.5 L/min for inorganic analytes) and add preservatives as prescribed in the project-specific FSP. For VOCs, be sure to fill the sample container with no headspace, minimizing overflow to prevent flushing of preservative from the container). Place sample containers in a resealable bag and store bagged samples in cooler. Record sample rate and time on Field Sampling Record form.

3.12 Shut down controller at end of discharge cycle and shut down compressor. Disconnect refill and discharge lines from controller and well cap. Store or disperse purge water as prescribed by the project-specific FSP.

3.13 Resecure well casing.

STANDARD OPERATING PROCEDURE 2, Revision 3.0
Groundwater Sample Collection Using a Peristaltic Pump

1.0 SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure (SOP) is to delineate protocols for well purging and groundwater sample collection using a Masterflex Model 7570-01 peristaltic pump. This procedure is typically used to collect samples from sumps, shallow wells not equipped with dedicated bladder pumps, or other vessels from which aqueous samples are required. The protocols for this procedure are designed to facilitate purging of stagnant water from the wells or other sampling devices and collecting representative aqueous samples. In addition, this SOP is intended to eliminate sample-collection conditions that could compromise sample quality (e.g., turbidity, aeration, cross contamination).

For shallow monitoring wells, the volume of water purged is equal to three times the volume of water standing in the well. The "3X well volume" is an arbitrary value specified by regulatory agencies (including the NC Department of Environment and Natural Resources [DENR]) attempting to ensure that samples of groundwater representative of actual conditions are collected, not stagnant water present in the well. Other sampling devices (e.g., sumps, drains) do not require purging of a specified number of volumes. However, the samples must be representative of the media sampled.

Project-specific Field Sampling Plans (FSPs) may prescribe collection of groundwater samples for a variety of laboratory analyses, and may prescribe collection of both unfiltered and filtered groundwater samples. If filtered samples are to be collected, a disposable high-capacity 0.45-micron filter capsule will be attached to the discharge line with decontaminated fittings/clamp, and the effluent from the filter capsule will be collected.

For most projects, the FSP will require collection of samples in the anticipated samples order of increasing contamination. To avoid impairment of samples from inappropriate preservatives or excessive turbidity, samples should be collected in the following order: 1) unfiltered and unpreserved inorganic analyte samples, 2) unfiltered and preserved inorganic analyte samples, and 3) filtered and preserved inorganic analyte samples.

Because the vacuum created by a peristaltic pump may cause loss of dissolved gases and potentially volatile analytes, samples to be collected for volatile organic compound (VOC) analyses after purging with a peristaltic pump must be collected using a bailer, syringe sampler, or, if accessible, by "dipping." These samples should be collected last in the sample sequence.

2.0 EQUIPMENT AND MATERIALS

a. Masterflex Model 7570-01 peristaltic pump
b. Dedicated flexible (C-Flex) tubing with stainless-steel tube weights
c. Insulated cooler with frozen ice packs
d. Polyethylene graduated cylinders (2,000 mL and 100 mL) and beakers (100 mL and 500 mL)
e. Disposable nitrile gloves
f. Sample containers and preservatives specified in the project-specific FSP
g. pH meter and conductivity/temperature meter (see SOPs 6 and 7) plus any other groundwater field parameter meters designated in the FSP
h. Resealable sample bags
i. Stopwatch
j. Purified water in spray bottle
k. Disposable laboratory wipes (e.g., Kimwipes)
l. Well-construction information (if not previously entered on Field Sampling Record form)
m. Field Sampling Record forms, project notebook, waterproof-ink pens
n. Calculator
o. Electric water-level indicator (see SOP 3)
p. Purge-water container buckets with lids
q. Trash bags

Note: If samples to be analyzed for VOCs are to be collected, disposable polyethylene bailer(s), an appropriate length of new 1/8-inch nylon cord, and appropriate sample containers and preservative are necessary. If filtered samples are to be collected, dedicated flexible (C-Flex) tubing, decontaminated polyethylene connectors, hose clamps, and new filter capsules are necessary.

3.0 PROCEDURE

3.1 Unlock/open well or sampling point and measure static water level from the surveyed measurement point (typically the top of the well riser pipe, sometimes identified by a survey mark) with electrical water level indicator (see SOP 3). Record water level on the Field Sampling Record form. Clean water-level probe with purified water and laboratory wipes.

3.2 If appropriate, calculate minimum required purge volume as follows:

For monitoring wells, the amount of water to be purged is equal to three times the volume of water present within the entire well, calculated as follows:

$$PV_s = 3 \bullet \pi \bullet (SD \div 24)^2 \bullet (SB - WD) \bullet 28.32$$

where

PV_s = purge volume for shallow well, in liters
SD = screen diameter, in inches
SB = depth to bottom of screen, in feet below measurement point (typically top of well riser pipe)
WD = measured depth to water, in feet below measurement point.

3.3 Connect tubing and pump assembly and lower intake tubing into the well to approximately 0.5 ft above the bottom of the well. A short piece of decontaminated stainless-steel tubing may be clamped to the end of the intake tubing to provide a weight. Adjust the variable speed regulator to allow the liquid to flow at a rate that will minimize turbulence. Contain or disperse purge water as designated in FSP.

3.4 Measure and record purge rate. Divide the purge volume (L) by the purge rate (L/min) to calculate purge time (min). Record purge rate and total purge time on Field Sampling Record form.

3.5 Measure drawdown of wells being purged with peristaltic pump and record on Field Sampling Record form. If a well pumps dry early in the purging cycle and, based on professional judgement, it is impractical to purge the entire purge volume calculated in Step 3.2, terminate purging and proceed with the remaining steps of this SOP once the water level in the well has sufficiently recovered.

3.6 Near the end of the purge cycle prior to sample collection, don nitrile gloves and collect purge-water sample in beaker for measurement of pH, specific conductance, and temperature (see SOPs 6 and 7) plus any other field-parameter measurements specified in the project-specific FSP. Record measurements on Field Sampling Record form. Clean instrument probes and beakers used for field-parameter measurement with a purified-water spray after each reading. Note: Minimize purge-water aeration in beaker when measuring dissolved oxygen and oxidation/reduction potential (ORP) by allowing the beaker to fill from the bottom.

3.7 After field parameters have been measured, fill inorganic analyte sample containers using peristaltic pump and add preservatives as prescribed in the project-specific FSP.

3.8 Place each sample in a resealable bag and store in cooler.

3.9 Lift sample tubing intake above water level, pump excess water from discharge tubing, and flush tubing with purified water. Retain dedicated tubing in bags labeled with sampling-point identification.

3.10 If VOC samples are to be collected, don nitrile gloves, attach bailer to cord, and slowly lower bailer through water column to the desired depth. Slowly retrieve bailer and pour contents into sample containers. Fill the sample container with no headspace, minimizing overflow to prevent flushing of preservative from the container.

3.11 Place sample containers in a resealable bag and store bagged samples in cooler.

3.12 Record sample time on Field Sampling Record form.

3.13 Resecure well casing or access port.

STANDARD OPERATING PROCEDURE 3, Revision 1.0
Field Measurement of Depth to Water in Wells Using an Electric Water-Level Meter

1.0 SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure (SOP) is to delineate protocols for measuring the depth to water (static water level) in wells using an electric water-level meter. The protocols for this procedure are designed to ensure measurements are accurate and precise and performed using non-contaminating procedures.

These water-level measurements may be used to establish groundwater flow direction and gradients, to assess seasonal water-level fluctuations, and to calculate the volume of the water column in individual wells (see SOPs 1 and 2).

Groundwater levels are to be measured with an electric water-level meter equipped with a graduated cable (or tape) long enough to measure the depth to water and delineated to the nearest 0.01 foot.

If well depths are to be measured (requires lowering the probe through the water column), the probe and cable should be decontaminated before the initial measurement. Measurements should be sequentially taken from the least to the most contaminated well. After measuring the depth of a well, the wetted part of the cable should be rinsed and wiped dry before proceeding to the next well. If only water levels are measured (i.e., only the probe comes in contact with the water), the probe should be rinsed and wiped dry before proceeding to the next well.

The accuracy of water level meter tapes are periodically checked using a steel measuring tape to evaluate whether the meter cable has either stretched or shrunk. The results of these calibrations should be recorded on the Equipment Calibration Record form and adjustment factors should be applied to measurements as needed.

2.0 MATERIALS

a. Electric water-level meter with probe
b. Spray bottle with purified water

c Alconox detergent and control water
d. Disposable laboratory wipers (e.g., Kimwipes)
e. Field Sampling Record forms, project notebook, waterproof-ink pens
f. Bucket

3.0 PROCEDURE

3.1 Decontaminate the water-level cable and probe by soaking the cable and probe in a bucket filled with an Alconox-water solution. Rinse and dry cable and probe.

3.2 Unlock protective casing lid, and slowly lower the water level tape into the well casing until the electronic indicator (buzzer and/or light) activates. Measure the depth to water by reading the graduation on the tape that is aligned with the reference point (survey mark) on the well casing. Repeat as necessary to obtain uniform measurement of water level in feet below top of reference point.

3.3 Record water level on field notebook/Field Sampling Record form, as appropriate.

3.4 Rinse probe with purified water and wipe dry.

3.5 Resecure well.

STANDARD OPERATING PROCEDURE 5, Revision 1.0
Surface-Water Sample Collection

1.0 SCOPE AND APPLICATION

This Standard Operating Procedure (SOP) specifies the protocol that should be used for collection of water samples from shallow surface waters and streams. These procedures are intended to obtain information on the quality of surface water.

2.0 MATERIALS

a. Sample container(s) and preservation specific in the project-specific Field Sampling Plan (FSP)
b. Spare sample containers
c. Field Sampling Record forms, project notebook, waterproof-ink pens

3.0 PROCEDURE

3.1 Generally, choose the deepest part of the pool or channel at the designated sampling location. Representative and uniform samples are collected from locations along flowing streams where the water is well mixed.

3.2 Whenever possible, surface-water samples should be collected directly into the sample bottle. The sample should be collected without disturbing the sediment. Care must be exercised not to displace the preservative from a pre-preserved sample container. If the water source is too shallow and the bottom sediment is likely to become suspended and enter the sample bottle, use a transfer vessel to collect the sample (except for volatile organic compounds [VOCs]).

3.3 Sample bottles pre-dosed with preservative should not be used. Before the sample is collected, fill the sample bottle filled three times with water from the stream/pool and discard the water downstream/downgradient and away from the collection point. Then collect the sample for laboratory analysis by holding the mouth of the sample container entirely below the water surface, if possible, but not dragging the bottom and causing resuspension of sediment. In flowing water, the mouth of the sample container should be directed upstream so flow is directly into bottle during the fill. After the sample has been collected, immediately apply preservation as specified in the project-specific FSP.

3.4 Document field observations in field notebook, for example:

- Sample location (e.g., coordinate location, or distance and direction from landmark)
- Position of collection point in pool
- Approximate size of pool if delineation is possible
- Depth of pool at point of collection
- Water coloration
- Flow rate

STANDARD OPERATING PROCEDURE 6, Revision 1.0
Field Measurement of Water-Sample Hydrogen Ion Concentration (pH)

MODEL 050450 pHTestr 2 pH Meter with ATC
MODEL pH-30 (Corning) pH Meter

1.0 SCOPE AND APPLICATION

This Standard Operating Procedure (SOP) specifies the protocol that should be used for measurement of pH in water. The procedures presented can be applied generally but are also specific to the use of the EXTECH phTestr 2 and the Corning ph-30 pocket sized meters. The phTestr 2 pH meter has a resolution of 0.1 and an accuracy of ±0.1 with the capability of three-point calibration. The Corning pH-30 meter has a resolution of 0.01, an accuracy of ±0.2 units, and the capability of two-point calibration; this meter does not automatically compensate for temperature change, but deviations more than 0.1 pH units would be realized for temperatures less than 25 °C and a maximum 0.02 pH deviation in response to temperature fluctuations.

The inclusion of the pHTestr 2 and pH-30 meters in this SOP is not intended as a mandate that only these meters can be used. Alternate types of electrodes or meters are acceptable, but specific SOPs may be required for their use. All calibration and maintenance activities should be documented on the Field Instrument Calibration and Maintenance Record form. Refer to the instrument documentation for conditioning and maintenance/routine service instructions.

2.0 MATERIALS

a. pH meter model pHTestr 2 or Corning pH-30
b. Buffer solutions pH 4.01, 7.00, and 10.01 (single-use buffer pouches are preferred)
c. Purified water in a spray bottle
d. Clean or disposable beaker at least 4 inches larger in diameter than probe body and deep enough to allow total submergence with probe tip at least 2-inches from bottom

e. Thermometer

f. Field Sampling Record forms, instrument-specific Field Instrument Calibration and Maintenance Record form, project notebook, waterproof-ink pens

3.0 PROCEDURES

3.1 Initialization

3.1.1 Turn on meter by pressing the ON/OFF button (phTestr 2) or slide on/off switch to on position (pH-30). Remove the cap and place probe in tap water or pH 4 buffer solution. If an error code ER 1 (pHTestr 2) is displayed the batteries should be changed. The display of the pH-30 meter will be blank, segmented, or fade after immersion if the batteries are too low for proper instrument operation. Since pH meters depend on the ability to generate a small electrical potential at the probe, it is important that fresh batteries are maintained in the meter for maximum operation. Slow response and excessive drift are indications that new batteries are needed.

3.1.2 If the probe has not been left dry (pH-30), conditioning is not necessary. If batteries are in good condition calibration can immediately be performed.

3.1.3 Field meters that are calibrated against more accurate laboratory instruments should remain on after calibration is complete and a calibration check should be performed after all measurements are complete. This step will not apply to groundwater samples unless otherwise noted.

3.2 Calibration

3.2.1 Calibration must be performed daily prior to data collection, after every 4 hours of operation, or more frequently if there seems to be significant instrument drift (i.e., greater than 1.5 pH units). Some meters have circuitry and programming that allow the meter to maintain calibration after being turned off. The pHTestr 2 has auto shut off but not the ability to check calibration internally without a reference solution.

3.2.2 Calibration is performed using fresh standard laboratory buffers pH 4.01, 7.00, and 10.01 (check buffer expiration date). Generally, as many of these buffers as possible should be used to calibrate the instrument when used to measure the pH of natural waters. Both the phTestr 2 and pH-30 allow three-point calibration.

3.2.3 Calibration should always start with a pH 7.00 buffer followed by pH 4.01 and then pH 10.01.

3.2.4 Always calibrate the instrument when it is equilibrated to ambient air temperature in a solution that is at a temperature close to the expected temperature of the water to be sampled. For groundwater measurements, use buffers stored at room temperature.

3.2.5 Follow calibration instructions for the meter used; the electronics of the meter will dictate the actual calibration steps. After conditioning (refer to manual), insert probe into pH 7.00 buffer solution (do not immerse PhTestr 2 into solution up to rubber seal or instrument housing will leak; both the pHTestr 2 and pH-30 should be immersed between 0.5 inch and 1 inch below surface of sample) and turn meter on.

3.2.6 Gently stir solution and allow display to stabilize. Note temperature (keep temperature probe at least 1 inch from pH probe, and use only a glass thermometer due to the potential interference with metal temperature probes).

3.2.7 To begin calibration of the pHTestr 2 push the CAL button on the front of the meter to enter calibration mode; when 7.00 or the closest reasonable value is displayed press the HOLD/CONfirm button to complete the calibration for that buffer. The pH-30 meter requires a manual adjustment and the trim screw at the top of the meter can be turned until pH 7.00 is displayed.

3.2.8 Rinse probe with purified water and shake off excess water.

3.2.9 Repeat the steps in 3.2.7 and 3.2.8 for pH 4.01 buffer solution. The meter will automatically make the necessary slope correction.

3.2.10 Repeat the steps in 3.2.7 and 3.2.8 for pH 10.01 buffer solution. The meter will automatically make the necessary slope correction. Calibration is complete.

3.2.11 After the last calibration, confirm the adjustments by inserting the probe into each buffer solution again starting with the pH 7.00 buffer and rinsing with purified water between solutions. If readings do not correspond to the buffer standards, use new buffers to confirm. The pH measurement of standard buffers should be within 0.5 pH units. If pH readings are not within 0.5 pH units, change the batteries in the meter, recalibrate, and retest; recondition the probe for a longer period, if necessary. If these steps do not improve the operation of the instrument, the meter(pHTestr 2)/probe (pH-30) should be replaced.

3.2.12 All calibration steps and results should be documented on the instrument-specific Field Instrument Calibration and Maintenance Record form along with any narrative explaining remedial steps and the final resolution.

3.3 pH Measurement

3.3.1 The pH of a water sample should be measured immediately after collection and after the temperature is measured. Measure and record the temperature of water sample.

3.3.2 Remove cap and turn unit on (Note: it is recommended that the pH-30 remain on between calibrations). Remove any other probes/sensors from the sample to avoid electrical interferences. The electrical potential used by the pH meter is much smaller than that used by a conductivity meter and therefore interference problems from surrounding objects that emit electrical fields are generally not significant. However, if an interference problem is suspected, the analyst should perform a test to evaluate possible interferences and use shielding as appropriate.

3.3.3 Place electrode at least 0.5 inches below water surface keeping probe toward center of container and at least 2 inches off bottom. There should not be any other probe in the container that emits an electrical field or is made of metal (e.g., conductivity probe/cell, metal thermistor, or ORP probe) as these may cause interference with the measurement.

3.3.4 Gently stir, especially if sample has been sitting for more than a few minutes.

3.3.5 Bring probe to a stationary position and allow display to stabilize. When the drift in the readings has decreased to less than ±0.2 pH units, take midpoint as result (note that some of the pHTestr 2 meters have a stable indicator in the display). If drift constantly exceeds 0.2 pH units, calibration should be checked.

3.3.6 Record pH measurement to nearest 0.1 pH unit on Field Sampling Record form.

3.3.7 Rinse probe and shake off excess water. At least once per every 10 measurements, repeat the measurement in the same sample aliquot and record on Field Sampling Record form. If the duplicate measurement is not repeatable to within ±0.2 pH units, check calibration (Section 3.4) and calibrate again, if necessary (Section 3.2).

3.4 Calibration Check

3.4.1 Calibration checks should be made if the meter is drifting, after 4 hours of use, or if there has been a significant ambient temperature change.

3.4.2 A final calibration check should always be made at the end of each day after the last sample has been collected.

STANDARD OPERATING PROCEDURE 7, Revision 1.0
Field Measurement of Water-Sample Temperature-Compensated Conductance (Specific Conductance)

YSI Model 30 Handheld Salinity, Conductivity, and Temperature System

1.0 SCOPE AND APPLICATION

This Standard Operating Procedure (SOP) specifies the protocol that should be used for measurement of conductivity in water. The procedures presented can be applied generally but are also specific to the use of the YSI Model 30 meter. The YSI Model 30 has multiple-parameter capability including temperature, salinity, conductivity, and specific conductance. The meter has the capability to measure temperature between -5 and 95 degrees Celsius with a 0.1 degree resolution and ±0.1 degree accuracy. When measuring specific conductance this meter has a variable resolution between 0.01 μS/cm (0 to 499.9 μS/cm) and 1.0 μS/cm (499.9 to 4,999 μS) for conductivity ranges typical of groundwater. The meter has a total operational range of 200 mS/cm (200,000 μS/cm). The YSI Model 30 meter has a sliding accuracy of ±0.5% of the full scale. The accuracy at low range (<499.9 μS/cm) is ±2.5 μS/cm and then steps down at the next range interval (>499.9 μS/cm ≤ 4,999 μS/cm) to ±24.9 μS/cm.

The inclusion of the YSI Model 30 meter in this SOP is not intended as a mandate that only this meter can be used. Alternate types of sensors or meters are acceptable, but specific SOPs may be required for the use of these instruments.

Conductivity is a numerical expression of an aqueous solution's capacity to carry an electrical current. The presence of dissolved ionic compounds makes water conductive and the total concentration and chemical characteristics (e.g., valence and mobility) dictate the level of conductance. The addition of salts, acids, or bases to water increases conductance most significantly, therefore the addition of H^+ and OH^- ions cause greater increases than equal amounts of any other ions. Conductivity measurements do not differentiate between individual ions, but give an indication of impurities (i.e., total dissolved solids) present.

Refer to the instrument documentation for conditioning and maintenance/routine service instructions.

2.0 MATERIALS

a. YSI Model 30 meter with conductivity cell
b. Manufactured or laboratory-prepared conductivity standards
c. Purified water in laboratory wash bottle
d. Clean or disposable beaker at least 4 inches larger in diameter than cell body and deep enough to allow total submergence with cell tip at least 0.5 inches from bottom
e. Mercury-filled thermometer
f. Shielding for beaker (0.5-inch thick wooden block, plastic beaker stand, or thick rubber mat)
g. Field Sampling Record forms, instrument-specific Field Instrument Calibration and Maintenance Record form, project notebook, waterproof-ink pens

3.0 PROCEDURE

3.1 Initialization

3.1.1 Note that maximum performance can only be attained if the batteries are fresh. Most meters will operate with weakened batteries but drift may be more pronounced and displays sluggish if the power source is not maintained. Also the accuracy of readings may deteriorate due to the sensors inability to operate at a normal range.

3.1.2 Press the ON/OFF button on face of meter. The meter will go through a self- test sequence that will take several seconds.

3.1.3 At the end of the self test the display should indicate the cell constant (i.e., 5.0/cm ±4%). If the self-diagnostic test reveals a problem, an error code will be displayed. Reference the Troubleshooting section of the instrument manual.

3.1.4 If no error codes are displayed the temperature will be indicated in the lower right corner of the display signaling the meter is ready for use. Measurements for environmental samples generally should be made in specific conductance mode. If the meter is in the specific conductance mode the temperature unit (°C) will be flashing. Specific conductance is the conductance of the solution if it were measured at 25 °C (i.e., a corrected conductance reading). If the "°C" is not flashing, slowly press the MODE button until it does, signaling that the meter is in the specific conductance mode.

3.1.5 Field meters that are calibrated against more accurate laboratory instruments should remain on after calibration is complete and a calibration check should be performed after all measurements are complete.

3.2 Calibration Check

3.2.1 System calibration is rarely required for the YSI Model 30 because the unit is calibrated at the factory and it is capable of automatic correction. However, the unit's accuracy will be checked against a high quality standard before each sampling event. The meter can make small automatic adjustments as the electrodes of the sensor (i.e., cell constant) abrade or otherwise deteriorate, but large adjustments will require manual calibration.

3.2.2 Follow initialization procedure (Section 3.1). If the instrument completes the self-test sequence successfully, check calibration as described below.

3.2.3 Always use a clean glass beaker and fresh new conductivity standards of a range recommended by the manufacturer as suitable for the cell (i.e., compatible with cell constant). Common standard solutions for conductivity are made from potassium chloride (KCl) and sodium chloride (NaCl). At least two standards should be used that bracket the expected range of values.

3.2.4 Fill beaker with enough solution to cover cell (i.e., over oval top opening of chambers) and allow at least 0.5 inches of space at bottom (i.e., do not rest cell on bottom of beaker to avoid interference and to allow flow through cell chambers). The standard solution should be allowed to warm to room temperature or as close to 25 °C (77 °F) as possible. Make certain that the work area is away from large metal objects or energized electrical equipment of any type (e.g., large batteries or collection of batteries, battery chargers, vehicles, metal bench tops, air conditioning/heating units, etc.). Also, no other probes/sensors should be in the beaker.

3.2.5 Rinse cell with purified water and shake off excess water. It is best if a few minutes can be allowed for the cell to completely dry. Immerse cell into aliquot of solution and allow time for the cell to stabilize with regard to temperature (approximately 60 seconds).

3.2.6 Move cell up and down and side to side in solution to make sure no air bubbles are trapped in the electrode chambers. When reading has stabilized, record value on the instrument-specific Field Instrument Calibration and Maintenance Record form, and compare the value to the standard value.

3.2.7 If reading is within 5 percent of the standard value then meter calibration is accurate and no further action or adjustment is necessary. Meter is ready for measurement of specific conductance. If reading is outside these limits carefully recheck calibration again. If second check confirms significant error refer to manual for instruction to check that temperature compensation is set to the default (i.e., 25 °C and 1.91 percent) for the YSI Model 30 meter. If temperature compensation is set properly, clean cell (Section 4.0) and recheck calibration. If after cleaning the calibration check still fails test, inspect carefully for missed residue or damage and, when satisfied with competence and cleanliness of cell, carefully perform manual calibration.

3.2.8 Rinse cell thoroughly with purified water, shake off excess water, and return cell to storage chamber.

3.2.9 Calibration, check results, and details of standard solutions used (e.g., date made, expiration date, type of solution [e.g., KCl, NaCl], standard value, tracking number, source) should be documented along with any narrative explaining procedure, remedial steps, and the final solution. The calibration result and associated error should be documented on the instrument-specific Field Instrument Calibration and Maintenance Record form.

3.3 Manual Calibration

3.3.1 Calibration of meters is specific to the instrument design, and the manual for the meter should be consulted for proper procedure. The following steps are for the YSI Model 30 meter.

3.3.2 Initialize instrument (Section 3.1).

3.3.3 Select a calibration standard with a conductivity within the range typical of samples to be measured and place 3 to 4 inches of the solution into a clean glass beaker.

3.3.4 Insert and suspend sensor in solution so that the bottom of the cell is at least 0.5 inches from bottom.

3.3.5 Allow at least 60 seconds for the temperature reading to become stable.

3.3.6 Move cell vigorously up/down and side to side to dislodge any air bubbles from the electrodes.

3.3.7 Press the up (▲) and down (▼) arrow keys at the same time. The CAL symbol will be displayed in the lower left corner of the screen indicating that the meter is in the calibration mode.

3.3.8 Use the up (▲) and down (▼) arrow keys to adjust the reading to the value of the calibration standard solution. The instrument automatically corrects temperature variation. Note that the arrow keys must be pressed or an error message will be displayed; turn meter off and start again.

3.3.9 Press the ENTER key once and the word "SAVE" will flash across the screen indicating that the procedure is complete.

3.3.10 Rinse cell thoroughly with purified water, shake off excess water and return cell to storage chamber.

3.3.11 Calibration results and details of standard solutions (e.g., date made, expiration date, type of solution [e.g., KCl, NaCl], standard value, tracking number, source) used should be documented on the instrument-specific Field Instrument Calibration and Maintenance Record form along with any narrative explaining procedure.

3.3.12 Repeat calibration check (Section 3.2).

3.4 Conductivity Measurement

3.4.1 Measurements should be made as close to the sample time as possible, but if the situation warrants, the conductivity of the sample can be measured up to 4 days after collection. Such delay is not typically warranted; however, if delayed measurement is necessary, samples must be stored chilled then adjusted to room temperature before measurement is made, and prior approval should be obtained from the Project Leader.

3.4.2 Initialize instrument (Section 3.1).

3.4.3 Place 4 to 6 inches of the sample into a clean 500 mL beaker or enough to cover sensor ports and allow 1 to 2 inches (0.25 inch minimum) of space between bottom of beaker and the bottom of the sensor. This will allow movement of the cell to induce the sample to flow through electrode chambers of the cell and also to avoid electrical interference with container material.

3.4.4 Insert and suspend sensor in sample so that the base of the cell is at least 0.5 inch from bottom and toward center 1 inch (0.25 inch minimum) from all sides of the beaker.

3.4.5 Allow at least 60 seconds for the temperature reading to become stable.

3.4.6 While keeping cell submerged, move vigorously up/down and side to side to dislodge any air bubbles from the electrodes and interior of chambers. It sometimes helps to tap the cell gently against the side of the beaker to dislodge any bubbles inside the chambers.

3.4.7 Hold beaker in hand to suspend above ground, or place beaker on 0.5-inch thick wood block, or thick rubber mat to isolate the sample and container from ground potential.

3.4.8 Make sure sample and sensor are at least 2 feet from motors or metal objects (e.g., well casings). Note: The analyst should make a series of measurements near and away from permanently fixed objects or commonly used equipment that could cause interferences to determine the effects from these. In case of interference use shielding, disconnect motors, or move away from area before making measurement.

3.4.9 Record measurement appropriately (e.g., 2,000 μS/cm ±5%). At least once for every 10 measurements, repeat measurement in the same sample aliquot and record on Field Sampling Record form. If duplicate measurement is not within 5 percent of original measurement, check calibration (Section 3.2).

3.4.10 Rinse cell thoroughly with purified water and shake off excess water. Return cell to meter storage chamber.

STANDARD OPERATING PROCEDURE 8

Field Measurement of Water-Sample Oxidation/Reduction Potential

ORPTestr Pocket Oxidation-Reduction Potential Meter

1.0 SCOPE AND APPLICATION

This Standard Operating Procedure (SOP) specifies the protocol that should be used for qualitative measurement of oxidation/reduction potential (also referred to as ORP or Redox potential) in aqueous samples. The procedures presented are specific to the use of the ORPTestr meter. This instrument is suitable for general water-quality measurement, however data application should be considered before using the equipment and techniques specified herein. The inclusion of the ORPTestr meter in this SOP is not intended as a mandate that only this meter can be used. Alternate types of electrodes or meters are acceptable, but specific SOPs may be required for the use/operation of these instruments.

Refer to the manual for instrument conditioning and maintenance/routine service information.

2.0 MATERIALS

a. ORPTestr Meter (from Cole-Parmer)
b. YSI 3682 Zobell ORP Reference Solution
c. Distilled water in laboratory wash bottle
d. Clean or disposable beaker deep enough to allow total submergence with probe tip at least 1 inch into solution
e. Field Sampling Record forms, instrument-specific Equipment Calibration Record form, project notebook, waterproof-ink pens

3.0 PROCEDURE

3.1 Calibration Check

3.1.1 Generally this meter does not require calibration. However, for this project an inspection should be performed prior to each sampling and whenever batteries are changed. First hold meter upside down and inspect probe tip for a bubble. If a bubble is present, note that the unit may not be suitable for use.

3.1.2 A calibration check is performed using a YSI 3682 (or equivalent) Zobell standard reference solution. The solution must be prepared using clean laboratory glassware and distilled/deionized water per the instructions that accompany the crystal salts. The solution should be transferred and stored in a clean glass bottle. The solution typically has a 6-month shelf life when stored in the refrigerator.

3.1.3 Rinse conditioned probe (i.e., free of crystal deposits) with distilled/deionized water. Rinse probe with Zobell solution into a waste container.

3.1.4 Pour 2 to 3 inches of solution into a clean beaker and immerse probe 1 inch into solution stirring once. The instrument may be rested on the bottom of the beaker in a position generally vertical.

3.1.5 Allow reading to stabilize for 2 to 5 minutes. Placing a smaller beaker containing the standard inside a deeper beaker and/or covering the larger beaker with plastic wrap or Parafilm may aid stabilization. While waiting measure the temperature with a glass thermometer (note that metal temperature sensors may cause interfere with the operation of the ORP probe) keeping thermometer at least 1 inch from probe.

3.1.6 Note reading of standard and temperature of solution, and compare to the table of concentrations supplied with the standard used. The ORP should approximate 231 mV at 25 °C. If the reading approximates the standard ORP the meter is ready to use, and record a calibration entry on the instrument-specific Equipment Calibration Record form. If the reading is not within 25 mV, attempt calibration procedure (Section 3.2) immediately without removing probe from solution.

3.1.7 Remove electrode form solution and rinse with distilled/deionized water. Replace cap. A small amount of the Zobell solution can be kept in cap to help keep electrode conditioned and improve probe reaction time.

3.2 Calibration Procedure

(Note: This calibration procedure is based on suggestions from the supplier technical-support staff).

3.2.1 The calibration step should proceed uninterrupted after the calibration check (Section 3.1). Press the CAL/CON button on the ORPTestr and the display will flash "CA" followed by the reading.

3.2.2 To adjust reading (Note: the electrode should still be in solution) press and hold the HOLD/INC button until the standard value (e.g., 230 mV ±5 at 25°C [77°F]) is displayed. Note that the meter will increment up from the standard reading. If the actual standard value is lower, continue to hold the HOLD/INC button and the ORP value will scroll to the upper limit (+1,050 mV), then continue to scroll past the lower limit (-50 mV), and will eventually reach the standard value.

3.2.3 Leaving the meter in the solution, press CAL/CON button and the display should show the calibration offset symbol (CO) indicating that an offset adjustment has been made. The offset will be retained in the memory of the instrument until the batteries are removed.

3.2.4 Perform a calibration check using the same standard solution. If the ORP reading is not within 25 mV, see Section 4.0. If a bubble is present in the probe, discard meter and replace with a new unit.

3.2.5 Remove electrode from solution and rinse with distilled/deionized water. Replace cap. A small amount of the Zobell solution can be kept in cap to help keep electrode conditioned and improve probe reaction time.

3.2.5 All calibration steps and results, along with any narrative explaining remedial steps and the final resolution, should be documented on the instrument-specific Field Equipment Calibration Record form.

3.3 ORP Measurement

3.3.1 Remove cap and press ON/OFF button to turn meter on. Fill glass or plastic beaker with 2 to 3 inches of sample. Immediately immerse probe into sample about 1 inch. Temperature and pH should be measured after ORP is measured or should be measured using a separate sample aliquot if stabilization time is more than 2 minutes.

3.3.2 Allow reading to stabilize.

3.3.3 The hold on (HO) button can be pressed to hold reading. After the HO button is pressed, the hold canceled (HC) button must be pushed or the unit must be turned off to unfreeze the display allowing additional measurements. Record ORP measurement on Field Sampling Record form.

3.3.4 Remove electrode form solution and rinse with distilled/deionized water after each measurement. Replace cap. A small amount of the Zobell solution can be kept in cap to help keep electrode conditioned and improve probe reaction time.

STANDARD OPERATING PROCEDURE 9

Field Measurement of Water-Sample Dissolved Oxygen Content

YSI Model 55 Dissolved Oxygen Meter

1.0 SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure (SOP) is to delineate protocols for field measurements of dissolved oxygen (DO) in water using the YSI 55 DO meter. Alternate instruments or methods may be used, but separate SOPs may be required.

The YSI Model 55 Handheld System has a digital meter, attached cable, and polarographic sensor probe, and has a measurement range between 0 to 20 mg/L or 0 to 200 percent air saturation. This instrument also displays temperature in degrees Celsius. Refer to the instrument manual for conditioning and instrument maintenance/routine service information.

2.0 MATERIALS

a. YSI Model 55 dissolved oxygen and temperature meter
b. Disposable nitrile gloves
c. Deionized water in a spray bottle
d. Field Sampling Record forms, instrument-specific Equipment Calibration Record form, project notebook, waterproof-ink pens
e. Decontaminated beaker
f. Lidded container for waste water
g. Laboratory wipers (e.g., Kimwipes)

3.0 PROCEDURE

3.1 Initially prepare the instrument by verifying that the calibration/storage chamber sponge is saturated. This creates a 100-percent water-saturated air environment conducive to ideal probe calibration and keeps the electrolyte from drying out during storage. Inspect membrane and o-ring for damage. Turn instrument on to verify that the batteries are charged.

3.2 Determine the approximate altitude of the sample area and the approximate salinity of the water to be analyzed.

3.3 Begin calibration of the instrument. It should be recalibrated each time it is turned on before taking measurements. Turn the meter on with the ON/OFF button. Wait for the dissolved oxygen and temperature readings to stabilize, approximately 15 minutes. Use two fingers to press and release both the up (▲) arrow and the down (▼) arrow keys at the same time. At the digital prompt for altitude, enter "0" (the altitude is input in hundreds of feet) and press ENTER. When the calibration value is displayed in the lower right of the display and the current dissolved oxygen reading is stable on the main display, press ENTER. At the digital prompt for salinity, enter "0." When the correct salinity appears on the LCD, press ENTER. All calibration steps and results, along with any narrative explaining remedial steps and the final resolution, should be documented on the instrument-specific Field Equipment Calibration Record form.

3.4 Insert probe into sample and stir the probe through the sample at a rate of approximately 1 foot per second to avoid stagnation which can result in artificially low readings.

3.5 Continue periodic dissolved oxygen measurements until readings have stabilized to +/- 0.1 mg/L.

3.6 Record measurement on Field Sampling Record form.

3.7 Dispose of sample in appropriate container or area.

3.8 Flush probe and beaker with deionized water spray, and dry beaker. Replace probe in storage chamber containing saturated sponge. Note: when taking measurements from a succession of wells, the meter may be left on.

STANDARD OPERATING PROCEDURE 11
Screening Samples and Packing Sample Coolers for Shipping

1.0 SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure (SOP) is to delineate protocols for screening samples that historically show total uranium levels above 0.02 mg/L and for packing sample coolers that must be shipped to the analytical laboratory.

The internal General Electric (GE) screening protocols for samples with historical total uranium levels above 0.02 mg/L are designed to meet Nuclear Regulatory Commission (NRC), Department of Transportation (DOT), and GE Facilities Licensing regulations for shipping samples offsite to external laboratories for analysis. These protocols require a 40-mL vial volume from an indicated well to be analyzed by the internal GE Chemet Laboratory. A GE-designed spreadsheet is generated by RTI for the indicated wells and, if the Chemet analysis result is below 0.02 mg/L, the sample is considered standard and may be delivered to the offsite laboratory without further screening. If the Chemet analysis result is greater than 0.02 mg/L and less that 0.5 grams total ^{235}U per shipment, GE Facilities Licensing personnel verify the laboratory's Special Nuclear Materials license and possession limit. If the analysis result is greater than 0.5 grams total ^{235}U per shipment, additional radioactive screening is required together with additional tracking to facilitate shipment of radioactive materials.

It is important that coolers are packed properly to prevent breakage of sample containers and to maintain proper sample temperature, particularly when the samples are shipped via overnight courier service.

If shipping hazardous materials above threshold volumes to the laboratory (e.g., methanol), the rules set forth in Title 49 of the Code of Federal Regulations (49 CFR) must be followed.

2.0 MATERIALS

a. Insulated coolers (hard plastic or metal)
b. Custody seals

c. Packing material (bubble wrap, Styrofoam, etc.)
d. Chain-of-custody form(s)
e. Clear packing tape
f. Duct tape
g. Sealing plastic bags
h. Ice and blue ice
i. Plastic garbage bags
j. Signed GE Facilities Licensing uranium level spreadsheet

3.0 SAMPLE COOLER PACKING PROCEDURE

3.1 Check the tightness of each sample container's lid and verify that labels are affixed and properly completed.

3.2 Compare sample numbers to chain-of-custody sheet(s) to verify all samples to be shipped are packed in the cooler(s).

3.3 Tape around lids if sample container is not self-locking.

3.4 Wrap glass sample bottles in bubble wrap, foam cells, or other protective sheeting.

3.5 Place sample containers in sealing plastic bags if not already packaged as such.

3.6 Place blue ice on the bottom of the sample cooler. Place layers of bubble wrap over the blue ice. Line the cooler with an open plastic garbage bag, place the samples and a temperature-blank vial (if required) upright inside the garbage bag, and seal bag.

3.7 Double-bag and seal loose ice in resealable plastic bags. Place the sealed bags of ice outside the garbage bags containing the samples.

3.8 Pack any extra space in the cooler with packing material such that the contents cannot shift during handling, even after the ice used in the cooler loses its shape after melting.

3.9 Enclose sample documentation (i.e, chain-of-custody forms, field parameter forms) in a sealing plastic bag and tape the bag to the inside of the cooler lid. If more than one cooler is being shipped, it should be noted on the documentation whether the contained information applies only to the samples within the individual cooler, or pertains to samples shipped in several coolers.

3.10 Seal the cooler with signed and dated custody seals so that the cooler cannot be opened without breaking the custody seal. Place clear packing tape over the custody seal to prevent incidental damage to the seal.

3.11 Tape the cooler shut with packing tape. Place duct tape over the cooler drain plug, if any.

3.12 Ship samples via an overnight delivery service. To ensure that the cooler does not run out of coolant while in the custody of the courier, the samples must be shipped for delivery on the next calendar day. If a weekend or holiday will prevent delivery of the samples on the next calendar day, retain custody of the samples and maintain the ice within the cooler until after the weekend or holiday.

STANDARD OPERATING PROCEDURE 12, Revision 1.0
Groundwater Sample Collection from High-Capacity Wells

1.0 SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure (SOP) is to delineate protocols for collecting groundwater samples from high-capacity wells (i.e., water-supply or recovery wells). These protocols are designed to facilitate collecting groundwater samples that are representative of actual aquifer conditions.

This SOP is intended to minimize sample-collection conditions that could compromise sample quality. These compromising conditions include excessive discharge pressure (particularly when sampling for volatile organic compounds [VOCs]), turbidity, unstable field parameters, introduction of atmospheric contamination, inadequate sample cooling conditions, and cross contamination between wells.

Project-specific Field Sampling Plans (FSPs) may prescribe collection of groundwater samples for a variety of laboratory analyses, and may prescribe collection of both unfiltered and filtered groundwater samples. If filtered samples are to be collected, a disposable high-capacity 0.45-micron filter capsule will be attached to the discharge line with decontaminated fittings/clamp, and the effluent from the filter capsule will be collected.

For most projects, the FSP will require collection of samples in the anticipated order of increasing contamination. To avoid impairment of samples from inappropriate preservatives or excessive turbidity, samples should be collected in the following order: 1) unfiltered and unpreserved inorganic analyte samples, 2) unfiltered and preserved VOC samples, 3) unfiltered and preserved inorganic analyte samples, and 4) filtered and preserved inorganic analyte samples.

2.0 EQUIPMENT AND MATERIALS

a. Insulated cooler with ice packs and cooler thermometer
b. Polyethylene graduated cylinder (100 mL)
c. Disposable nitrile gloves

d. Sample containers and preservatives specified in the project-specific FSP
e. pH meter and conductivity/temperature meter (see SOPs 6 and 7) plus any other groundwater field parameter meters designated in the FSP
f. Resealable sample bags
g. Stopwatch
h. 5-gallon plastic bucket with lid
i. Purified water in spray bottle
j. Disposable laboratory wipes (e.g., Kimwipes)
k. Field Sampling Record forms, project notebook, waterproof-ink pens
l. Electric water-level indicator (see SOP 3)

Note: If filtered samples are to be collected: dedicated flexible (Tygon or C-Flex) tubing, decontaminated polyethylene connectors, hose clamps, and new filter capsules will be necessary.

3.0 PROCEDURE

3.1 Notify appropriate site-maintenance personnel of expected sampling of process-water and/or potable-water wells.

3.2 Unlock well house and determine operating status of well pump (observe flow meter on discharge piping). Record operating status of pump (ON/OFF) on the Field Sampling Record form.

3.3 Measure static water level from surveyed measurement point (typically the top of the stilling tube) with an electrical water level indicator (see SOP 3). Record water level on the Field Sampling Record form. Clean water-level probe with purified water and laboratory wipes.

3.4 If the well pump is OFF, locate electric operational panel and switch from AUTO or OFF status to HAND, MANUAL, or ON position. After pumping has initiated, calculate the pumping rate in gallons per minute by dividing an arbitrary quantity of water (e.g., 50 gallons) by the time required to pump the volume. Record the pumping rate (in gallons per minute) on the Field Sampling Record form. Allow pumping to continue in the well for at least 15 minutes to purge the well of standing water and to flush the wellhead piping.

3.5 If the well pump is ON, calculate the pumping rate in gallons per minute by dividing an arbitrary quantity of water (e.g., 50 gallons) by the time required to pump the volume. Record the pumping rate on the Field Sampling Record form.

3.6 Spray the stainless steel triplicate sampling ports with purified water and wipe ports with laboratory wipe. Turn gate valve at sampling port to initiate flow through sampling tubes, capturing discharge in a 5-gallon plastic bucket.

3.7 Don nitrile gloves and collect purge-water sample in beaker for measurement of pH, specific conductance, and temperature (see SOPs 6 and 7) plus any other field-parameter measurements specified in the project-specific FSP. Record measurements on Field Sampling Record form. Clean instrument probes and beakers used for field-parameter measurement with a purified-water spray after each reading. Note: Minimize purge water aeration in beaker when measuring dissolved oxygen and oxidation/reduction potential (ORP).

3.8 Fill sample containers and add preservative, as appropriate. If sampling for VOCs, minimize flow to as near to 0.100 L/min as possible using a graduated cylinder and stopwatch. Insert VOC sample containers in triplicate sample holders and fill, minimizing turbulent flow during filling.

3.9 Record sample date and time on the Field Sampling Record form, as well as any other sampling comments.

3.10 Return pump switch setting to original position and close and secure well house.

3.11 Discard purge water as described in FSP.

Appendix B

Quality Assurance Project Plan for Monitoring of Nitrate in Waste Treatment Area Groundwater and Surface Water

RESEARCH TRIANGLE INSTITUTE

RTI Report No. 6448-020/003/01F

December 22, 1999

Quality Assurance Project Plan for Monitoring of Nitrate in Waste Treatment Area Groundwater and Surface Water

Prepared for:

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Quality Assurance Project Plan for Monitoring of Nitrate in Waste Treatment Area Groundwater and Surface Water

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List of Acronyms and Abbreviations

CEMQA	RTI Center for Environmental Measurements and Quality Assurance
COC	chain-of-custody
DENR	North Carolina Department of Environment and Natural Resources
DO	dissolved oxygen
DWQ	North Carolina Division of Water Quality
EHS	GE Site Environment, Health & Safety
EPA	U.S. Environmental Protection Agency
FSP	Field Sampling Plan
GE	General Electric
HNO_3	nitric acid
HPS	High Purity Standards, Inc.
H_2SO_4	sulfuric acid
ICP-MS	inductively coupled plasma mass spectrometry
LCS	laboratory control sample
LOQ	limit of quantitation
mg/L	milligrams per liter
MS	matrix spike
NIST	National Institute of Standards and Technology
ORP	oxidation/reduction potential
PE	performance evaluation
QA	quality assurance
QAPP	Quality Assurance Project Plan
QC	quality control
%R	percent recovery
RPD	relative percent difference
RTI	Research Triangle Institute
SM	*Standard Methods for the Examination of Water and Wastewater* (APHA, et al., 1992)
SNM	special nuclear material
SOP	standard operating procedure
SW-846	*Test Methods for Evaluating Solid Waste, Physical/Chemical Methods* (EPA, 1997a)
T15A NCAC	Title 15A of the North Carolina Administrative Code
TOC	total organic carbon
^{235}U	uranium isotope 235
UV-IR	ultraviolet infrared analyzer
WT	waste treatment

1.0 Introduction

This Quality Assurance Project Plan (QAPP) was prepared by Research Triangle Institute (RTI) and designates and documents the specifications and methods that will be employed to help establish technical accuracy and precision, statistical validity, and documentary evidence of data generated during the monitoring of groundwater contamination identified near the Waste Treatment (WT) Facility of the General Electric (GE) site in Wilmington, North Carolina. This QAPP is included as Appendix B of the *Waste Treatment Area Investigation Report* (RTI Report No. 6448-020/001/01F; December 22, 1999) and will be the quality-controlling document for activities relating to the collection and analysis of groundwater and surface-water samples which are described in the project Field Sampling Plan (FSP) (RTI Report No. 6448-020/002/01F; December 22, 1999) prepared for this monitoring program and included in the *Area Investigation Report* as Appendix A. This QAPP will be used in conjunction with the FSP and will help ensure that the data obtained for this project are of sufficient quality to meet the project-specific objectives described below.

This QAPP contains general and specific information regarding field sampling, laboratory, and analytical procedures. Field and laboratory personnel are provided with instructions regarding activities to be performed before, during, and after field investigations. The specific protocols that pertain to various aspects of the field activities are described in the project FSP. The quality assurance/quality control (QA/QC) protocols included in this QAPP are adopted by reference in the FSP.

This QAPP was prepared in general accordance with U.S. Environmental Protection Agency (EPA) guidelines described in *EPA Guidance for Quality Assurance Project Plans, EPA QA/G-5* (EPA, 1998). Other documents that have been referenced in this plan include *Standard Methods for the Examination of Water and Wastewater* (APHA, et al., 1992) and *Contract Laboratory Program National Functional Guidelines for Inorganic Data Review* (EPA, 1994a).

2.0 Project Description

A hydrogeologic investigation recently conducted in the WT area of the GE-Wilmington facility revealed a groundwater contaminant plume in the principal aquifer consisting of elevated concentrations of nitrate and ammonia. The plume is fully on site and does not pose a threat to neighboring properties or receptors. The suspected source of the contamination is leakage from one or both of two basins that contain an aqueous nitrate waste. GE has addressed the suspected leakage by replacing the liners in both of these basins and by removing in-ground piping and a sump previously situated between the two basins.

Investigation results suggest that natural attenuation of the nitrate plume may be occurring. Using natural-attenuation parameters that are reasonable for this geochemical system, fate and transport modeling predicts that the position of the nitrate contamination plume would be stable and that the maximum nitrate concentrations in groundwater would fall below the North Carolina groundwater standard within approximately 5 years. Contaminant transport modeling predicts that, if no natural-attenuation processes were occurring, the ammonia and nitrate plumes would be contained by GE's active pumping-well network. In this highly conservative scenario, the maximum nitrate concentration in groundwater is predicted to fall below the North Carolina groundwater standard within approximately 14 years. Recommendations in the *Area Investigation Report* include routine monitoring of groundwater and surface-water quality to better understand the degree to which natural attenuation processes are occurring, along with regular reporting to the North Carolina Department of Environmental and Natural Resources (DENR).

2.1 Purpose and Objectives

Consistent with EPA's directive on monitored natural attenuation (EPA, 1997), continuation of the recently initiated routine surface-water and groundwater monitoring program is intended to accomplish the following:

- Demonstrate that natural attenuation is occurring;
- Identify toxic transformation products, if applicable;
- Evaluate whether the plume is expanding in size;

- Detect new releases of contaminants that could impact the groundwater system being monitored;
- Demonstrate efficacy of institutional controls, if applicable;
- Detect changes in environmental conditions that may reduce the efficacy of the natural-attenuation processes; and
- Evaluate when North Carolina groundwater standards have been met.

2.2 Discussion of Activities

The media to be monitored include surface water, surficial-aquifer groundwater, and principal-aquifer groundwater. Samples are collected quarterly, are analyzed in the field for non-critical parameters, and submitted to analytical laboratories for measurement of project-critical parameters.

2.2.1 Target Analytes. The target analytes for this project include three project-critical analytes and several non-critical analytes as follows:

Project-Critical Parameters
nitrate
total and isotopic* uranium
ammonia

* Isotopic analysis is performed only on samples with a total uranium concentration of 0.002 mg/L or above.

Non-Critical Parameters
Natural-Attenuation Indicator Parameters
pH
oxidation/reduction potential (ORP)
dissolved oxygen (DO)
total organic carbon (TOC)
Other Non-Critical Field Parameters
temperature
specific conductance

As described in the *Area Investigation Report*, the above natural-attenuation indicator parameters characterize geochemical conditions and are measured to interpret whether conditions are conducive for natural attenuation and/or to indicate whether natural-attenuation processes have been occurring.

2.2.2 Data Use. The data generated during this project will be used to evaluate the spatial distribution of and temporal trends for inorganic contaminants in groundwater and surface water in the waste treatment area. Specifically, monitoring of these waters will enable GE and RTI to:

- Verify numerical flow-model predictions that principal-aquifer groundwater flow paths from the north WT basins terminate at wells WW-13 and WW-14 and that the only potential receptors of the identified principal-aquifer groundwater contamination would be workers that come in contact with the facility production water (not used as drinking water) pumped from these wells, should the contamination ever reach that far;

- Update the contaminant transport modeling predictions of future plume configurations by incorporating a more accurate understanding of the degree to which natural-attenuation processes are occurring;

- Monitor for any potential breakthrough of anthropogenic uranium from the nitrate waste, which is currently observed to be effectively attenuated by the geologic materials situated between the basins and the principal aquifer; and

- Identify if an evaluation of additional remedial measures, such as in-situ enhancement of biological denitrification (e.g., soluble or insoluble carbon source injection), is warranted.

3.0 Project Organization

The project organization is presented in Figure 1 and is discussed in the following subsections.

3.1 Role of General Electric

The GE Site Environment, Health & Safety (EHS) staff have overall responsibility for coordinating the work being performed by its site assessment consultant, the RTI Geosciences Department, RTI's analytical laboratory, and laboratories directly contracted by GE. GE will be responsible for reviewing and approving the reports prepared by RTI, forwarding these reports to the regulatory agencies, and responding to the regulatory agencies regarding the data that are generated during this project. GE also reserves the right as client to review, inspect, and/or audit any aspect of work being coordinated by RTI and analytical laboratories. For this project, Mr. Herbert R. Strickler and Mr. Thomas R. Crawford serve as principal contacts between RTI, GE management, and appropriate regulatory agencies (Figure 1).

3.2 Role of Analytical Laboratories

Two analytical laboratories will be responsible for analyzing samples for project-critical parameters. These laboratories are: (1) Oxford Laboratories, Inc. (Oxford), of Wilmington, North Carolina, who will analyze samples for nitrate and ammonia, and (2) RTI's Center for Environmental Measurements and Quality Assurance (CEMQA) Laboratory in Research Triangle Park, North Carolina, who will analyze samples for total and isotopic uranium.

In addition, Oxford will be responsible for analyzing samples for TOC, a non-critical parameter. TOC analyses will be conducted at least once each year.

Each of these laboratories has demonstrated acceptable qualifications and experience to perform the respective analytical methods and is allowed to receive special nuclear material (SNM). The NC Division of Water Quality (DWQ) Chemistry Laboratory certifies laboratories for nitrate and ammonia analyses under 15A NCAC 2H .0800 (there is no required certification for uranium analyses), and Oxford holds the required certifications.

3.2.1 Laboratory Directors. The two laboratories identified above have primary responsibility for the analytical measurements made on this project. The laboratories' directors are responsible for overseeing laboratory operations and ensuring that the analytical measurements reported by the laboratory are in compliance with the protocols outlined in their QAM. They also are responsible for reviewing, commenting on, and approving the portions of this QAPP that relate to their responsibilities; performing final review of analytical data; and approving the analytical data for reporting and submission to RTI.

3.2.2 Laboratory Quality Assurance Officers. The laboratories' QA Officers will perform the following tasks:

- Review, comment on, and approve portions of this QAPP that relate to their responsibilities;
- Coordinate with RTI on any proposed deviation from the QAPP;
- Perform analytical data review and approval throughout the laboratory work;
- Conduct internal audits at any point throughout laboratory work, from sample receipt through analysis; and
- Coordinate with the RTI Project Leader or QA Officer on possible requests for re-analysis or supplemental QA/QC data to help explain any analytical discrepancies.

3.3 RTI Project Leader

The RTI Project Leader, Mr. Andrew D. Stahl, is responsible for technical oversight of the program and for assuring that RTI's work is conducted in accordance with the QA requirements. The Project Leader will:

- Ensure that the program is appropriately organized with effective lines of communication and that program responsibilities and authorities for making critical QA decisions are clearly understood;
- Distribute and enforce this QAPP;
- Consult with the Project QA Officer on proposed deviations from the QAPP and, with consent from the Project QA Officer, approve deviations from the QAPP;
- Review QA suggestions or reports from the Project QA Officer and ensure that the actions taken are timely and appropriate;

- Report project status, problems, and corrective actions as required by the GE contract and the QAPP; and
- Review work products and reports and issue approvals once satisfied that QA goals are met.

3.4 Lead Field Geologist

The Lead Field Geologist, Ms. Carolyn Keith, is responsible for day-to-day supervision of on-site activities and for compliance with the FSP and QAPP. Within these duties Ms. Keith will:

- Inform the Project Leader of the schedule and status of field activities;
- Oversee sampling activities and ensure they are conducted in conformance with the FSP and QAPP;
- Delegate Team Leader responsibility to other qualified personnel, when necessary, in order to maintain project schedule;
- Routinely inspect the work being performed and document the results in the project records;
- Anticipate problems in the performance of the assigned task, and select prevention, detection, and remedial action in conjunction with the Project Leader and/or QA Officer;
- Review QA suggestions or reports from the Project QA Officer; communicate these problems to appropriate staff; develop corrective action for identified or anticipated problems; and ensure that the corrective actions are performed properly and timely and are documented in the project records; and
- Propose and justify QAPP deviations to the Project QA Officer and implement deviations that are approved by the QA Officer and the Project Leader.

3.5 Field Team Members

Field Team Members report on project matters directly to the Lead Field Geologist. Field Team Members will:

- Assist the Lead Field Geologist in equipment and sample container preparation, sampling, and documentation of field activities;
- Follow the FSP and QAPP;

- Obtain approval for QAPP deviations from the Project Leader through the Lead Field Geologist; and
- Immediately report QA problems to the Lead Field Geologist and the Project QA Officer and help resolve problems.

3.6 Project Quality Assurance Officer

The Project QA Officer, Andrea C. McWilliams, is responsible for keeping the Project Leader informed of the status of project QA/QC compliance and identifying QA/QC problems. Ms. Cynthia Salmons will serve as QA technical advisor to Ms. McWilliams. The Project QA Officer will:

- Distribute and enforce the QAPP;
- Review analytical strategies with the Project Leader to ensure that program QA requirements are addressed;
- Inform staff of program and project QA requirements;
- Conduct or designate appropriate personnel to conduct audits of systems, activities, or data to assess QA/QC compliance of sample collection, analysis, handling, and documentation;
- Report audit results to the Project Leader and, with the Project Leader, evaluate problems and identify appropriate corrective actions;
- Review and document corrective actions, and report the status of these actions to the Project Leader; and
- Review any proposed QAPP deviations with the Project Leader for approval;
- Perform or oversee validation of analytical laboratory reports;
- Prepare data validation reports; and
- Report overall QA/QC program status to the Project Leader.

4.0 Quality-Control Elements

This section presents QC requirements relevant to the analysis of environmental samples that will be followed during project analytical activities. The purpose of the QC program is to produce data of known quality that satisfy the project objectives and that meet or exceed the requirements of the standard methods of analysis. This program provides a mechanism for ongoing control and evaluation of data quality measurements.

The data collected for this project fall into the category of definitive data. Definitive data are generated using rigorous analytical methods, such as approved EPA reference methods. Definitive data are analyte-specific, and both the identification and the quantification of the analyte are confirmed. The methods have standardized QC and documentation requirements. The use of definitive data is not restricted unless quality problems require data qualification.

Some QC elements established for this program apply only to the analysis of project-critical parameters (nitrate, ammonia, and uranium) because only these analytical reports will be subject to data validation. As discussed in Section 9.0, the laboratory analytical reports generated for non-critical natural-attenuation indicator parameters (i.e., TOC) will receive a QA completeness check to ensure that the method-required QC analyses are performed with acceptable results. The particular aspects of this QAPP that are limited to the analysis of project-critical parameters are the discussions regarding QC samples (Section 4.2), QC acceptance criteria (Section 5.0), and data-validation procedures (Section 9.0).

4.1 Quality-Control Procedures

The chemical data to be collected during this monitoring program will be used to evaluate groundwater and surface-water quality in the WT area, and it is critical that these data be of the highest quality. In addition to following the QA/QC requirements presented in the specified analytical methods, project-specific QA/QC procedures will include:

- Adhering to protocols for field sampling procedures prescribed in the FSP;
- Collecting appropriate field blanks for laboratory analysis to monitor for cross-contamination of samples in the field or the laboratory;

- Laboratory analysis of blind field duplicate samples and double-blind performance evaluation (PE) samples to evaluate analytical precision and accuracy;
- Performing laboratory duplicate analyses and matrix spike (MS) analyses on groundwater samples collected specifically at the GE-Wilmington site for further evaluation of analytical precision and accuracy;
- Attaining completeness goals.

4.1.1 Use of Dedicated Sampling Equipment. Water samples will be collected using dedicated sampling equipment (e.g., dedicated down-well sampling pumps and dedicated tubing attached to surface pumps). Dedicated sampling equipment precludes the introduction of contaminants from one sampling location to the next due to improperly decontaminated sampling equipment. Use of dedicated equipment also enhances consistency in the manner in which samples are collected from one sampling event to the next. Dedicated bladder pumps are installed in the principal-aquifer monitoring wells. The dedicated tubing attached to each pump is lined with Teflon™ which will not adsorb and desorb contaminants. Similarly, peristaltic pumps are used to sample surficial-aquifer monitoring wells, and the tubing and foot valve used at each well is dedicated to the well. Surface-water samples are collected directly into new sample containers.

4.1.2 Standard Materials. Standard materials used to calibrate equipment and to prepare samples will be traceable to the National Institute of Standards and Technology (NIST), EPA, or other equivalent sources. The standard materials will be current. The expiration date will be established by the manufacturer or will be based on chemical stability, the possibility of contamination, and environmental and storage conditions. Standard materials will be labeled with expiration dates, and will reference primary standard sources if applicable. Expired standard materials will be discarded in accordance with applicable federal, state, and local restrictions.

4.1.3 Supplies. Supplies will be inspected before use in the field or laboratory. The descriptions of sampling and analysis methods will be used as a guide for establishing the acceptance criteria for related materials. A current inventory and appropriate storage system for these materials will help ensure their integrity prior to use. The efficiency and purity of supplies will be monitored through the use of standard materials and blank samples.

4.1.4 Holding Time Compliance. Sample preparation and analysis will be completed within the maximum holding time specified for the method. The holding time begins at the time of sample collection. The maximum holding time for the analyses to be performed for this project are presented in Table 1. Analysis completion, as used to assess holding times, is defined as the completion of all analytical runs, including dilutions, and any required re-analyses. If holding times are exceeded, and the analyses are performed, the associated results will be qualified as described in the data-validation procedure (Section 9.0).

4.2 Quality-Control Samples

QC samples will be collected as part of the overall QA/QC program. The purpose of this QA/QC program is to produce data of known quality that satisfy project objectives and that meet or exceed the requirements of the standard methods of analysis. This program provides a mechanism for ongoing control and evaluation of data-quality measurements through the use of QC materials. The acceptance criteria associated with the following QC analyses are discussed in Section 5.0, and the data-validation procedures used to evaluate whether any associated sample results need qualification are presented in Section 9.0.

4.2.1 Field Blanks. A field blank gives an indication of contamination induced from sample containers, preservatives, or the field environment (e.g., atmospheric vapors or wind-blown particulates). Commercially available purified water will be used for preparing the field blanks to be analyzed for nitrate, ammonia, and total uranium. Each field blank will be prepared in the field by pouring purified water from the bottle supplied by the laboratory into unused sample containers, adding the same chemical preservatives as used for the primary samples, and submitting the field blanks blind to the laboratories for analysis. Two field blanks will be collected each sampling event.

4.2.2 Laboratory Reagent Blanks. A laboratory reagent blank (method blank) consists of deionized, distilled water or solvent that is prepared by the laboratory and analyzed as a sample. Analysis of the reagent blank indicates potential sources of contamination from laboratory procedures (e.g., contaminated reagents, improperly cleaned laboratory equipment, or persistent contamination due to presence of certain compounds in the ambient laboratory air). At least one reagent blank will be analyzed for nitrate with each analytical batch of 20 or fewer samples, at least one reagent blank will be analyzed for uranium with each analytical batch of 15 or fewer samples, and at least one reagent blank will be analyzed for ammonia each day analyses are performed.

4.2.3 Matrix Spike Samples. MS analyses are performed by the laboratory in order to evaluate the efficiency of the sample analytical procedure. This evaluation is necessary because interference from the sample matrix may have a widely varying impact on the accuracy and precision of the analysis. The MS is prepared by adding known quantities of target compounds (i.e., the spike) to a sample for which the quantities of the same target compounds have already been determined. The spiked sample is extracted and analyzed. The results of the MS analysis are compared with the known spike additions, and a MS percent recovery (%R) is calculated. The calculated recovery gives an evaluation of the accuracy of the extraction and analysis procedures.

For uranium analyses, at least one MS analysis will be performed with each analytical batch of 20 or fewer samples. For nitrate and ammonia analyses, at least one MS analysis will be performed with each analytical batch of 10 or fewer samples. The laboratory will perform these analyses using groundwater samples collected from the GE-Wilmington site. The volumes of sample provided to the laboratory for uranium, nitrate, and ammonia analyses are sufficient for the initial analysis and a MS analysis. For nitrate and ammonia, Oxford selects which samples will be subjected to MS analyses. For uranium, the chain-of-custody (COC) form will indicate which samples are to be used for MS analyses. These samples will be selected by field personnel considering historical concentrations so that spiked samples are likely to contain detectable uranium concentrations lower than the concentration of the spiking solution.

4.2.4 Laboratory Duplicate Samples. To evaluate analytical precision, the laboratories will perform duplicate analyses of samples at minimum frequencies of 1 per 10 for nitrate and ammonia and 1 per 20 for uranium, and will calculate relative percent differences (RPDs) between the primary and duplicate analyses. Because the volume of sample provided to the laboratory is sufficient for the initial analysis and a duplicate analysis, the laboratories will select which samples will be analyzed in duplicate.

4.2.5 Field Duplicate Samples. Field duplicate samples will be collected and analyzed to evaluate sampling and analytical precision. Field duplicates will be collected in the same manner as the primary samples by filling twice the number of containers required for a single sample and submitting one set of these containers to the laboratory as a blind sample for analysis by the same analytical method requested for the primary sample. Two field-duplicate pairs will be collected for each sampling event for analysis of nitrate, ammonia, and uranium. Field duplicate samples will be collected at locations that are suspected to contain detectable concentrations of target analytes, but not at concentrations where sample dilution would be expected. Good agreement between the primary and duplicate sample results indicates good sampling and analytical precision.

4.2.6 Performance Evaluation Samples. PE samples will be analyzed to evaluate the accuracy of the laboratories' nitrate and uranium analytical procedures. The PE sample contains a predetermined set of parameters at known, certified concentrations. The PE samples will be double blind--at the time the analysis is performed, the analyst will not know which sample submitted by the field team is the PE sample, nor what analyte concentrations the PE sample contains.

The uranium and nitrate PE samples will be prepared by, and purchased from, High Purity Standards (HPS) of Charleston, South Carolina. Because PE samples are submitted to the laboratories blind, RTI provides HPS with containers to be filled with the PE samples. The PE vendor then fills these containers with the PE samples, adds required preservative, and sends the containers to the RTI Lead Field Geologist for inclusion in the sample delivery group.

4.2.7 Other Method-Required Control Samples and Standards. In accordance with the selected analytical methods, the laboratories are required to analyze several other control samples and standards including laboratory control samples (LCSs) and calibration check standards.

5.0 Data Quality Acceptance Criteria

Data quality acceptance criteria have been specified for the data to be generated as part of the activities governed by this QAPP. These criteria will help ensure that the groundwater investigations will be conducted and documented in a manner such that the collected data are sufficient and of adequate quality to meet the intended uses.

The basis for assessing the elements of data quality is discussed in the following subsections. In the absence of laboratory-specific precision and accuracy limits, the QC limits presented in this section must be met. Section 9.0 presents the data-validation procedures that will be used to evaluate whether any groundwater and surface-water sample analytical results associated with QC analyses need qualification on the basis of the data quality acceptance criteria discussed below. In some cases, the QC acceptance criteria that the laboratories are required to meet differ from those criteria used in the data-validation process. These two sets of acceptance criteria are summarized in the following sections and in Table 2.

5.1 Precision

Precision measures the reproducibility of repetitive measurements. It is strictly defined as the degree of mutual agreement among independent measurements as the result of repeated application of the sample process under similar conditions. Duplicate results are assessed using the RPD between duplicate measurements. The RPD is calculated as follows:

$$RPD = (200)\ (X_1 - X_2)\ /\ (X_1 + X_2)$$

where X_1 is the larger of the two observed values, and X_2 is the smaller of the two observed values.

5.1.1 Analytical Precision. Analytical precision is a measurement of the variability associated with duplicate or replicate preparation and analyses of the same sample in the laboratory, and is evaluated by analysis of laboratory QC samples, such as duplicate control samples and sample duplicates. If the recoveries of analytes in the specified control samples are comparable within established control limits, then precision is within limits. For analysis of nitrate, ammonia, and uranium on this project, laboratory precision will be assessed by calculating the RPD between laboratory duplicate analyses performed at the frequencies stated in Section 4.2.4.

The laboratories will take appropriate corrective action and, if necessary, re-analyze the analytical batch and re-perform the duplicate analyses if the RPD for laboratory duplicate analyses is greater than 10 percent. If the RPD for these QC analyses still exceeds 30 percent, the associated sample results will be qualified by RTI as described by the data-validation procedures.

5.1.2 Total Precision. Total precision is a measurement of the variability associated with the entire sampling and analytical process. It is evaluated by analysis of duplicate or replicate field samples, and measures variability introduced by both the laboratory and field operations. For this project, blind field duplicate samples will be analyzed to assess field and analytical precision (see Section 4.2.5). If a calculated RPD for the results of primary and blind-duplicate field samples exceeds 50 percent, data will be qualified as described by the data-validation procedures.

5.2 Accuracy

Accuracy is a statistical measurement of correctness and includes components of random error (variability due to imprecision) and systematic error. It reflects the total error associated with a measurement. A measurement is accurate when the value reported does not differ from the true value or known concentration of the spike or standard. Accuracy is expressed as %R and is calculated as follows:

$$\%R = (100)\ (X_s - X)\ /\ T$$

where X_s is the measured value of the spiked sample or the standard solution, X is the measured value of the unspiked sample ($X = 0$ for standard solutions), and T is the true value of the spike or standard solution.

5.2.1 Analytical Accuracy. As discussed in Section 4.2, laboratory accuracy will be assessed by analyzing method blanks, MS samples, double-blind PE samples, and LCSs.

Oxford Laboratory's acceptance criteria for nitrate and ammonia MS and LCS analyses is 90 to 110 %R. The RTI CEMQA Laboratory's acceptance criteria for uranium MS and LCS analyses are 80 to 120 %R and 90 to 110 %R, respectively. The acceptance criteria for method blank analyses is that no target analytes are detected. If the current acceptance criteria are not met for any of these QC analyses, the laboratory will take appropriate corrective action and, if necessary, re-analyze the analytical batch and re-perform the associated QC analyses. If, however, an acceptable LCS analysis indicates that matrix interference may be responsible for an unacceptable MS analysis, the laboratory may assess that the analytical batch of samples does not need to be re-analyzed.

Data will be qualified according to the data-validation procedures (Section 9.0) if the accuracy acceptance criteria are not met. For the purpose of data validation, the %R acceptance criteria for uranium, nitrate, and ammonia MS, LCS, and PE-sample analyses is 80 to 120 %R.

5.2.2 Field Accuracy. Field accuracy will be assessed through the analysis field blanks. Analysis of blanks will monitor errors associated with the sampling process, field contamination, sample preservation, and sample handling. The acceptance criteria for field equipment blanks are that all values are less than the reporting limit for each analyte.

5.3 Representativeness

Representativeness is the degree to which data accurately and precisely represent selected characteristics of the media sampled. Representativeness of data collection is addressed by careful preparation of sampling and analysis programs. This QAPP, together with the FSP, address representativeness by specifying sufficient and proper numbers and locations of samples; incorporating appropriate sampling methodologies; specifying proper sample collection techniques, use of dedicated sampling equipment; selecting appropriate laboratory methods to prepare and analyze samples; and establishing proper field and laboratory QA/QC procedures.

5.4 Completeness

Completeness is the amount of valid data obtained compared to the amount that was expected under "ideal" conditions. The number of valid results divided by the number of possible results, expressed as a percentage, determines the completeness of the data set. A sample will be considered valid if it meets the data quality acceptance criteria for precision, accuracy, and representativeness. The objective for completeness is to recover at least 90 percent of the planned data to support field efforts.

5.5 Comparability

Comparability is an expression of confidence with which one data set can be compared to another. The objectives of comparability are to ensure that the data developed during the investigation are comparable with the historical water-quality data and with applicable criteria or standards. The issue of comparability is addressed by specifying field and laboratory methods and QA/QC procedures that are consistent with the current standards of practice as approved by EPA and DENR.

5.6 Sensitivity

The laboratories must be able to perform the prescribed analytical method with appropriate sensitivity to provide reliable results that meet investigation objectives. The RTI CEMQA Laboratory and Oxford Laboratory limits of quantitation (LOQs) for uranium, nitrate, and ammonia analyses are 0.00015 milligram per liter (mg/L), 0.1 mg/L (as nitrogen [N]), and 0.21 mg/L (as N), respectively.

6.0 Field Procedures

The use of well-defined, accepted sampling procedures is a prerequisite for the acquisition of defensible data. This section describes the sampling and handling procedures that will be followed for each sampling event.

6.1 Sample Collection and Field Measurements

The collection of high-integrity environmental samples is critical to the quality of the chemical data generated. Consequently, standard operating procedures (SOPs) have been developed to provide strict, standardized field procedures that will be employed for field data measurements and sample collection. The SOPs are presented in the project FSP. Additional field procedures described in the FSP will be followed during sampling activities, including the collection of appropriate field QC samples and the QA procedures described in this section.

6.2 Sample Containers, Preservation, and Maximum Holding Times

Table 1 presents the sample containers, preservation, and maximum holding times for the samples to be collected for this program.

At each sampling location, one 250-milliliter (mL) polyethylene bottle and one 500-mL polyethylene bottle will be filled and submitted to Oxford for nitrate and ammonia analyses, respectively, and a 250-mL polyethylene bottle will be filled and submitted to the RTI CEMQA laboratory for uranium analysis. At least once each year, an additional 250-mL polyethylene bottle will be filled and submitted to Oxford for TOC analysis. RTI purchases new certified-clean polyethylene bottles from scientific equipment vendors (e.g., Cole Parmer or VWR Scientific).

Samples to be analyzed for total and isotopic uranium must be preserved with nitric acid (HNO_3) and samples submitted for ammonia and TOC analyses must be preserved with sulfuric acid (H_2SO_4). RTI purchases certified reagent-grade HNO_3 and H_2SO_4 from a scientific equipment vendor and creates 50-percent dilutions using commercially available purified water. Immediately after each sample is collected for these analyses, the appropriate 50-percent solution is added to each sample bottle in the field using a dropper bottle dedicated for this use to lower the sample pH to less than 2.

The maximum sample holding times for nitrate, ammonia, and uranium analyses are 48 hours, 28 days, and 6 months respectively.

6.3 Sample Handling and Storage

After sample collection, sample containers destined for laboratory analysis will be wiped clean with a paper towel and identified by labeling the bottles with an indelible marker or by affixing waterproof adhesive labels. At a minimum, the containers will be marked with the sample identification number and the requested analyte(s) to be measured. Except for the containers filled for uranium analysis, the containers will be placed in a clean cooler or on-site refrigerator and kept chilled until they are received by the laboratory. The cooler will contain sufficient coolant to chill the samples to less than 6 °C until they are transferred to the refrigerator or relinquished to the laboratory. The on-site refrigerator will be maintained approximately at 4 ± 2 °C. As currently required by the NC DWQ Laboratory, the samples will be stored and maintained between 0.1 and 4.4 °C while at the laboratory. Samples to be analyzed for uranium will be stored in clean coolers with no refrigerant until they are relinquished to the analytical laboratories.

It is important that coolers are packed properly to prevent breakage of sample containers and to maintain proper sample temperature, particularly when the samples are shipped via overnight courier service. An SOP for packing sample coolers for shipment is presented in the FSP. The laboratories will immediately notify the RTI Project Leader if conditions or problems are identified that require immediate resolution. Such conditions include container breakage, missing or improper COC forms, holding-time exceedances, missing or improper sample labeling, or frozen water samples.

6.4 Sample Custody

For each sample to be submitted for laboratory analysis, an entry will be made on a COC form. The information to be recorded includes the sampling date and time, sample identification number, requested analytes and methods, the number of containers per sample, and sampler's name. A separate COC form will be prepared for each of the involved laboratories. RTI's generic COC form will be used for the samples being submitted to Oxford and RTI CEMQA Laboratory.

Field team members will maintain custody of the samples until they are relinquished to the on-site refrigerator or to the courier service. The COC form will accompany the samples from the time of collection until they are received by the laboratory. Each party in possession of the samples (except the professional courier service) will sign the COC form signifying receipt. As described in the FSP, the COC form will be placed in a plastic bag and shipped with samples inside the cooler. A copy of the original completed form will be provided by the laboratory along with the report of results.

After the uranium samples and COC forms are packed in the coolers, custody seals will be placed on the lid of each cooler before the cooler is relinquished to the professional courier service. Custody seals provide assurance that the samples are not tampered with during transportation to the laboratory. Upon receipt, the laboratory will inspect the condition of the custody seals and report the information on the COC form. Samples for nitrate, ammonia, and TOC analyses will be hand delivered to Oxford Laboratory by a sampling team member, and so custody seals are not necessary for these sample coolers.

7.0 Laboratory Analytical Procedures

A summary of the analytical methods and laboratories selected for this monitoring program is as follows:

Laboratory Name/Location	Analytes	Method	Event
Oxford Laboratories, Inc./ Wilmington, NC	ammonia	SM 4500-NH_3-E	quarterly
	nitrate	SM 4500-NO_3-F	
	TOC	SM 5310-C	annual
RTI CEMQA Laboratory/ Research Triangle Park, NC	total and isotopic* uranium	EPA Method 200.8	quarterly

* Isotopic analysis is performed only on samples with a total uranium concentration of 0.002 mg/L or above.

7.1 Laboratory Analysis of Project-Critical Parameters

Oxford will analyze samples for nitrate using an automated cadmium reduction method (Standard Method [SM] 4500-NO_3-F) and for ammonia using a distillation/titration method (SM 4500-NH_3-E) (APHA, et al., 1992). The RTI CEMQA Laboratory will analyze samples for total uranium by EPA Method 200.8 (EPA, 1994b). This method employs inductively coupled plasma mass spectrometry (ICP-MS). The ICP-MS has the capability of measuring total uranium in a sample or the concentration of the individual uranium isotopes ^{234}U, ^{235}U, and ^{238}U. The laboratory initially will measure the total uranium concentration of each sample. For those samples found to have a total uranium concentration of 0.002 mg/L or greater, the laboratory also will measure the concentration of each of the three individual uranium isotopes.

7.2 Laboratory Analysis of Non-Critical Parameters

At least once each year, Oxford will analyze samples for TOCs by method SM 5310-C which utilizes an ultraviolet infrared analyzer (UV-IR). This procedure provides rapid and precise measurement of organic carbon in water.

8.0 Data Documentation And Reporting

The RTI Geoscience Department QA program includes implementation of an SOP that governs the management of sample collection and analysis documentation and data. This section presents project-specific reporting requirements relevant to the data produced during project sampling and analytical activities.

8.1 Field Documentation

Field instrument calibration records and parameter measurements will be recorded on the required field forms. Examples of field documentation forms are attached to the FSP. Units of measure for field analyses are identified on these forms. The field data will be reviewed by the RTI Project Leader to evaluate completeness of the field records and on-going appropriateness of the employed field methods. Field records will be retained in the project files.

8.2 Laboratory Data Reporting

At a minimum, Oxford and RTI CEMQA Laboratory analytical reports will include the following data and summary forms:

- Narrative, cross reference, and method references;
- Completed COC form and statement of condition of samples upon receipt;
- Analytical results and sample-specific LOQs and dilution factors;
- Summary of calibration information;
- Blank results for each analytical batch;
- Laboratory duplicate analytical results for each analytical batch;
- LCS recoveries for each analytical batch; and
- MS recoveries for each analytical batch.

Data validation will be employed to assess for bias and to review for completeness, representativeness, and acceptable levels of precision and accuracy. Should a more comprehensive data review be warranted, the laboratories will provide supporting documentation, including associated raw data.

9.0 Data Validation

The laboratory analytical reports generated for analysis of project-critical parameters will be evaluated through the process of data validation. Data validation is the procedure of reviewing data against a known set of criteria to verify data validity prior to use. Results of the data-validation review will be documented and summarized in a data-validation report. One data-validation report will be generated by the project QA Officer each quarter. The RTI Project Leader will review the data-validation report to assess if the project's data quality objectives have been met. In addition, the laboratory analytical reports generated for non-critical natural-attenuation indicator parameters will receive a QA completeness check to ensure that the method-required QC analyses are performed with acceptable results.

9.1 Validation Criteria

Each analytical laboratory report will be reviewed for compliance with the applicable method and for the quality of the data reported. The application of data-validation criteria is a function of project-specific data quality acceptance criteria (see Section 5.0). Data-validation components include review of the following information/analytical results:

- Data completeness,
- Holding times,
- Field and laboratory blank analyses,
- Field duplicate analyses,
- LCS analyses,
- MS analyses,
- Laboratory duplicate analyses,
- PE sample analyses, and
- Compound identification and quantification.

9.2 Standard Operating Procedures for Data Validation

The *EPA Contract Laboratory Program National Functional Guidelines for Inorganic Data Review* (EPA, 1994a) (*National Functional Guidelines*) provide general data-validation guidelines that can be applied to the data. RTI has employed these guidelines to develop a project-specific data-validation SOP. This data-validation procedure is documented and maintained in the project file. Each sample analysis batch for project-critical parameters will be validated using the SOP upon receipt of the associated analytical report from the laboratory.

9.3 Data Qualifiers

The data-validation procedures described in the *National Functional Guidelines* are designed to review each data set and identify biases inherent to the data including assessment of laboratory performance, overall precision and accuracy, representativeness, and completeness. The data-validation qualifiers (flags) given in the guidelines will be applied to those sample results which fall outside of specified tolerance limits, and, therefore, do not meet the program's QA objectives. An explanation of the data-validation qualifiers is provided in Table 3.

10.0 Performance and System Audits

Audit programs are established and directed by the QA staff to ensure that field and laboratory activities are performed in compliance with project-controlling documents. This section describes responsibilities, requirements, and methods for scheduling, conducting, and documenting audits of field and laboratory activities.

10.1 Description of Audits

Field audits focus on the appropriateness of personnel assignments and expertise; availability and proper use of field equipment; adherence to project controlling documents for sample collection, identification, handling, and transport; proper collection and handling of QC samples; and adherence to established COC and documentation procedures. Laboratory audits include reviews of sample handling procedures, internal sample tracking, SOPs, analytical data documentation, QA/QC protocols, and data reporting.

10.2 Audit Schedule

Audits will be scheduled to adequately monitor field and laboratory activities and will be conducted at least annually. The need for additional audits will be evaluated if significant changes in project scope or personnel develop, or if specific issues (e.g., performance discrepancies) that might warrant more frequent audits of either field or laboratory practices are identified.

10.3 Reports to Management and Responsibilities

Upon completion of any audit, the auditor will submit to the RTI Project Leader a report or memorandum describing any problems or deficiencies identified during the audit. It is the responsibility of the Project Leader to evaluate if the deviations will result in adverse effect on the project conclusions. If it is assessed that corrective action is necessary, procedures outlined in Section 12.0 will be followed.

11.0 Preventive Maintenance

Procedures specific to the calibration, use, and maintenance of field equipment are presented in the FSP. Maintenance procedures will be as prescribed in the manufacturer's specifications and will be performed by trained personnel. The analytical laboratories are responsible for analytical equipment calibration and maintenance. Should the services of subcontractors be employed at any time, they will be responsible for maintenance of equipment needed to carry out subcontracted duties.

12.0 Corrective Action

Corrective actions are initiated whenever data quality indicators suggest that data quality acceptance criteria have not been met. Corrective actions begin with identifying the source of the problem. Potential problem sources include failure to adhere to method procedures, improper data reduction, equipment malfunctions, or systemic contamination. The first level of responsibility for identifying the problems and initiating corrective action lies with the analyst/field personnel. The second level of responsibility lies with any person reviewing the data. Corrective actions may include more intensive staff training, equipment repair followed by a more intensive preventive maintenance program, or removal of the source of systemic contamination. Once resolved, the corrective action procedure will be fully documented, and if data quality acceptance criteria were not met, the samples in question may be recollected and/or re-analyzed utilizing a properly functioning system.

13.0 References

American Public Health Association (APHA), American Water works Association, and Water Environment Federation. 1992. *Standard Methods for the Examination of Water and Wastewater.* 18th edition.

Research Triangle Institute (RTI). 1999. *Waste Treatment Area Investigation Report.* RTI Report 6448-020/001/01F.

U.S. Environmental Protection Agency (EPA). 1994a. *Contract Laboratory Program National Functional Guidelines for Inorganic Data Review.* Office of Emergency and Remedial Response. Washington, DC. EPA-540/R-94-012.

U.S. EPA. 1994b. *Methods for Determination of Metals in Environmental Samples.* Supplement I. EMSL-CI. EPA/600/R-94/111.

U.S. EPA. 1997. *Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites.* Office of Solid Waste and Emergency Response Directive No. 9200.4-17. Washington, DC.

U.S. EPA. 1998. EPA Guidance for Quality Assurance Project Plans, EPA QA/G-5. Office of Research and Development. Washington, DC. EPA/600/R-98/018.

FIGURE

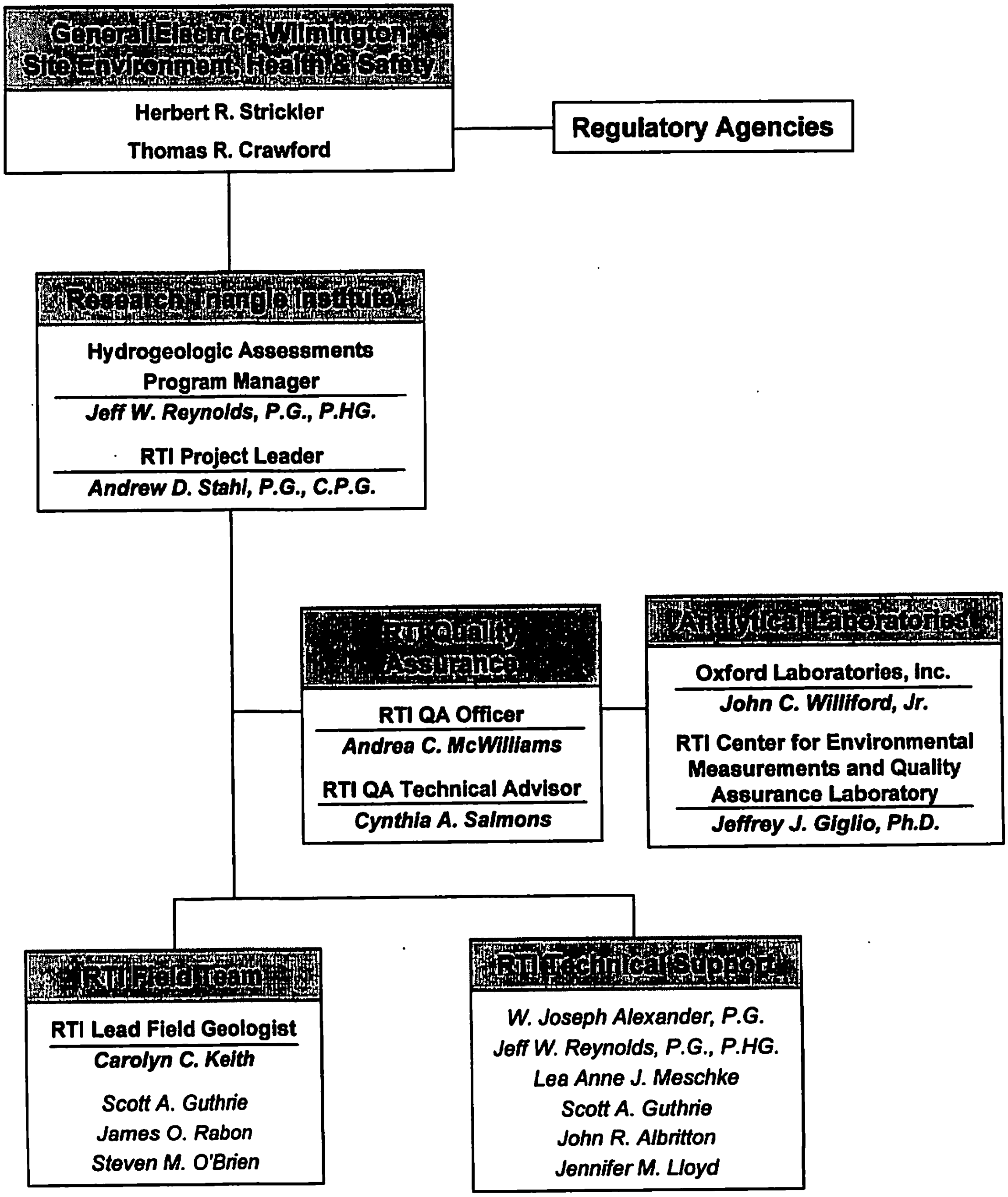


Figure 1
Project Organization

TABLES

Table 1
Sampling Plan Summary

Laboratory/ Location	Analyte	Analytical Method	Maximum Holding Time	Container	Preserv-ative	Sampling Event	Number of Samples Each Sampling Event			
							Primary Sample	Duplicate[a]	Field Blank[a]	PE Sample[b]
RTI CEMQA Laboratory/ Research Triangle Park, NC	Total and Isotopic[d] Uranium	EPA 200.8	6 months	1 polyethylene bottle, 250 mL	HNO_3 ($pH < 2$)	quarterly	27 (1 per sampling location)	2	2	1
Oxford Laboratories, Inc./ Wilmington, NC	Nitrate	SM 4500-NO_3-F	48 hours	1 polyethylene bottle, 250 mL	chilled [c]	quarterly	27 (1 per sampling location)	2	2	1
	Ammonia	SM 4500-NH_3-E	28 days	1 polyethylene bottle, 500 mL	H_2SO_4 ($ph < 2$), chilled [c]		27 (1 per sampling location)	2	2	0
	Total Organic Carbon	SM 5310-C	28 days	1 polyethylene bottle, 250 mL	H_2SO_4 ($ph < 2$), chilled [c]	annual	22 (1 per monitoring well)	1	0	0

[a] Quality-control sample submitted blind to analytical laboratories.

[b] Performance evaluation sample submitted as a double-blind sample to the analyical laboratories.

[c] Upon sample collection, samples will be maintained in a cooler with sufficient coolant to chill the samples to less than 6 °C until received by the analytical laboratory. While in the laboratory, samples will be stored and maintained between 0.1 and 4.4 °C as required by the North Carolina Division of Water Quality Chemistry Laboratory.

[d] Isotopic analysis is performed only on samples with a total uranium concentration of 0.002 mg/L or above.

Table 2
Quality-Control Acceptance Criteria

Analyte	Parameter	Frequency	Laboratory QC Acceptance Criteria	Data Validation QC Acceptance Criteria
Uranium	Method Blank	1 per 15 samples	< detection limit	< detection limit
	Laboratory Control Sample (LCS)	1 per 15 samples	90-110 %R	80-120 %R
	Matrix Spike	1 per 20 samples	80-120 %R	80-120 %R
	Laboratory Duplicate Analysis	1 per 20 samples	≤ 10 RPD	≤ 30 RPD
	Field Blank	2 per sampling event	—	< detection limit
	Field Duplicate	2 per sampling event	—	≤ 50 RPD
	Performance Evaluation Sample	1 per sampling event	—	80-120 %R
Nitrate	Method Blank	1 per 20 samples	< detection limit	< detection limit
	LCS (calibration check standard)	1 per 20 samples	90-110 %R	80-120 %R
	Matrix Spike	1 per 10 samples	90-110 %R	80-120 %R
	Laboratory Duplicate Analysis	1 per 10 samples	≤ 10 RPD	≤ 30 RPD
	Field Blank	2 per sampling event	—	< detection limit
	Field Duplicate	2 per sampling event	—	≤ 50 RPD
	Performance Evaluation Sample	1 per sampling event	—	80-120 %R
Ammonia	Method Blank	1 per day	< detection limit	< detection limit
	LCS (calibration check standard)	1 per day (of each)	90-110 %R	80-120%R
	Matrix Spike	1 per 10 samples	90-110 %R	80-120%R
	Laboratory Duplicate Analysis	1 per 10 samples	≤ 10 RPD	≤ 30 RPD
	Field Blank	2 per sampling event	—	< detection limit
	Field Duplicate	2 per sampling event	—	≤ 50 RPD

%R = percent recovery
RPD = relative percent difference

Table 3
Explanation of Data-Validation Qualifiers

Data Qualifier (Flag)	Data Qualifier Explanation
J	The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.
Jh	The approximate concentration is probably biased towards higher values than the actual concentration of the analyte in the sample.
Jl	The approximate concentration is probably biased towards lower values than the actual concentration of the analyte in the sample.
Jr	The analyte was positively identified above the method detection limit, but the numerical value is approximate because the detected concentration is below the practical quantitation limit.
R	The sample results are rejected due to serious deficiencies in the ability to analyze the sample and meet quality control criteria. The presence or absence of the analyte cannot be verified.
U	The analyte was analyzed for, but was not detected above the reported sample quantitation limit.
Ub	The sample result is qualitatively suspect because the analyte was detected in a field and/or laboratory blank at a similar level.
UJ	The analyte was not detected above the reported sample quantitation limit. However, the reported quantitation limit is approximate and may or may not represent the actual limit of quantitation necessary to accurately and precisely measure the analyte in the sample.

Appendix C

Field Lithologic Logs

Logging Performed by Research Triangle Institute

WT Area Investigation Borings/Piezometers
WT Area Investigation Borings/Monitoring Wells
Historical WT Area Borings/Monitoring Wells

Logging Performed by Law Engineering

Historical WT Area Borings/Monitoring Wells

WT Area Investigation Lithologic Logs

Borings/Piezometers

Logging Performed by Research Triangle Institute

Boring Number	Piezometer Number
WTB-01	WTP-01
WTB-02	WTP-02
WTB-03*	none
WTB-04*	none
WTB-05	WTP-05
WTB-06	WTP-06
WTB-07	WTP-07
WTB-08	WTP-08
WTB-09	WTP-09
WTB-10	WTP-10
WTB-11*	none
WTB-12	WTP-12
WTB-13	WTP-13
WTB-14	WTP-14
WTB-15	WTP-15
WTB-16	WTP-16
WTB-17	WTP-17
WTB-18*	none
WTB-19	WTP-19
WTB-20	WTP-20
WTB-21	WTP-21
WTB-22	WTP-22
WTB-23	WTP-23

* see Figure 1-2 for boring/piezometer location

☑ BORING
☐ EXCAVATION

FIELD LITHOLOGIC LOG

SITE NAME AND LOCATION W of Abandoned ZS WT CAF Assessment - WT Perimeter Rd	PROJECT NO. 6448-019	BORING / EXCAVATION NO. WTB-1
DRILLING CONTRACTOR Skipper Well Drilling	DRILLING METHOD Push Drive Probe Circa Geoprobe	SHEET 1 OF 2
DRILLER R. Skipper	SAMPLING METHOD Hammered Core	DRILLING START TIME 09:20 / FINISH TIME 10:02
DRILLER R. Malpass		
GEOLOGIST C. Keith / RTE	WEATHER 90's - W 5 - Sunny	START DATE 8-19-98 / FINISH DATE 8-19-98
DRILL RIG Concord 9200	SURFACE CONDITIONS graded Road shoulder	
ANGLE Vert. / BEARING —		
DATUM Land Surface / ELEVATION —	COORDINATES —	

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
0.0	0.0	4.0	#1	0.0-0.7 DARK BROWN ORGANIC VF to Silty SAND		90%			Easy			
1.0				0.7-1.2 - Salt : Pepper Brown / White Slightly organic VF Sand								
				1.2-1.5 Brownish Black mostly Silty Sand								
				1.5-1.7 Brown to Black mostly Silty Sand								
				1.7-1.9 Black VF Sand								
2.0				1.9-2.5 Brownish grey VF Sand								
				2.5-3.2 - Brownish Black mostly Silty Sand								
3.0												
4.0	4.0	8.0	#2	4.0-4.5 - grey : Black F-VF Sand		100%	Well Casing		Easy		5.16 - 8.21.98	
5.0				4.5-6.0 - Gradational into DARK Brownish Black organic very silty F-VF Sand								
6.0				6.0-6.7 - tan/Brown Clayey VF Sand								
7.0				6.7-8.0 - tan VF Sand sparse Clay nodules gradational into light greenish grey VF Sand								
8.0												

BORING TERMINATED AT 14.0 FT BLS. LOGGED BY: C. Keith

COMMENTS:

☑ BORING
☐ EXCAVATION

FIELD LITHOLOGIC LOG

SITE NAME AND LOCATION W of ABAndoned Z's WT CAF Assessment-WT Perimeter Rd	PROJECT NO. 6448-019	BORING / EXCAVATION NO. WTB-1
DRILLING CONTRACTOR Skipper Well Drilling	DRILLING METHOD Push Drive Probe CIRCA Geoprobe	SHEET 2 OF 2
DRILLER R. Skipper	SAMPLING METHOD Hammered Core	DRILLING START TIME 09:20 / FINISH TIME 10:02
DRILLER R. Malpass		
GEOLOGIST C. Keith / RTE	WEATHER 90's – WS – Sunny	START DATE 8-19-98 / FINISH DATE 8-19-98
DRILL RIG Concord 9200	SURFACE CONDITIONS graded Road shoulder	
ANGLE Vert. / BEARING —		
DATUM Land Surface / ELEVATION —	COORDINATES —	

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
8.0	8.0	10.0	#3	8.0 – 10.0 Grey VF Sand gradational down into med Brown VF to silty Sand		100%	← Well Casing		Moderate			
9.0												
10.0	10.0	12.0	#4	10.0 – 12.0 – Med. Brown VF saturated Sand		100%			Easy			
11.0												
12.0	12.0	14.0	#5	12.0 – 12.2. Med clayey Brown F Sand 12.2 – 12.4 Brown Sandy clay 12.4 – 13.6 – Greenish Grey Clay with Large wood particles		90%			Moderate			
13.0												
14.0												

BORING TERMINATED AT 14.0 FT BLS.   LOGGED BY: C. Keith

COMMENTS:

☑ BORING
☐ EXCAVATION

FIELD LITHOLOGIC LOG

SITE NAME AND LOCATION: Rd - between Cw 4C & 4B WT CaF Assessment - 450' W of WT perimeter
PROJECT NO.: 6498-019
BORING / EXCAVATION NO.: WTB-2
DRILLING CONTRACTOR: Skipper Well Drilling
DRILLING METHOD: Push Drive Probe / Circa GeoProbe
SHEET: 1 OF 2
DRILLER: R. Skipper
SAMPLING METHOD: Hammered Cone
DRILLING START TIME: 09:35
DRILLING FINISH TIME: 10:12
DRILLER: R. Malpass
GEOLOGIST: C. Keith / RTI
WEATHER: 90s - WS - Sunny
START DATE: 8-18-98
FINISH DATE: 8-18-98
DRILL RIG: Concord 9200
SURFACE CONDITIONS: improved grassed grade
ANGLE: Vert.
BEARING: —
DATUM: Land Surface
ELEVATION: —
COORDINATES: —

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
0.0	0.0	4.0	#1	0.0 - 0.95 - Mottled Light Brown to tan/orange Fine Sand		100%	Well Casing		moderate			
1.0				0.95 - 2.0 BLACK silty ORGANIC VF Sand								
2.0				2.0 - 4.0 Brown to dark Brown VF Sand - moist at Bottom								
3.0												
4.0	4.0	8.0	#2	4.0 to 6.0 - Brown to dark Brown VF to silty moist to saturated Sand - gradational		95%			moderate			
5.0												
6.0				6.0 - 6.6 - Light grayish tan VF Sand with wood particles - gradational						6.0	6.0 - 09:40 - 8-18-98 5.23 - 8-21-98	
7.0				6.6 - 7.4 - dark Brown silty VF Sand with 7.8 - 7.4 gradational grey tan VF Sand								
8.0												

BORING TERMINATED AT 12.0 FT BLS.
LOGGED BY: C. Keith
COMMENTS:

☐ EXCAVATION

FIELD LITHOLOGIC LOG

SITE NAME AND LOCATION RI - Between CW 9B & FC WT CAF Assessment - 450' W of WT perimeter	PROJECT NO. 6448-019	BORING / EXCAVATION NO. WTB-2
DRILLING CONTRACTOR Skipper Well Drilling	DRILLING METHOD Push Drive Probe Circa Geoprobe	SHEET 2 OF 2
DRILLER R. Skipper	SAMPLING METHOD Hammered Core	DRILLING START TIME 09:35 / FINISH TIME 10:12
DRILLER R. Malpass		
GEOLOGIST C. Keith / RTI	WEATHER 90's - W5 - Sunny	START DATE 8-18-98 / FINISH DATE 8-18-98
DRILL RIG Concord 9200	SURFACE CONDITIONS improved grass grade	
ANGLE Vert. / BEARING —		
DATUM Land Surface / ELEVATION —	COORDINATES —	

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
8.0	8.0	10.0	#3	8.0-8.25 Light Greenish tan VF Sand	⁖	60%			Moderate to easy			
				8.25-8.4 Greenish Grey Clay	≡							
				8.4-8.85 Greenish Grey F-VF Sand - Gradational	⁖							
9.0				8.85- 9.2 - Light Grey F-VF Sand	⁖							
10.0	10.0	12.0	#4	10.0-10.6 - Grey F - VF Sand	⁖	60%			Moderate to easy			
11.0				10.6 - 11.2 - DRK Blackish Grey Stiff Clay	≡							
12.0												

BORING TERMINATED AT 12.0 FT BLS.   LOGGED BY: C. Keith

COMMENTS:

☐ EXCAVATION

FIELD LITHOLOGIC LOG

SITE NAME AND LOCATION Rd - on CW 4 RD WT CAF Assessment - 165' West of WT perimeter	**PROJECT NO.** 6498-019	**BORING / EXCAVATION NO.** WTB-3
DRILLING CONTRACTOR Skipper Well Drilling	**DRILLING METHOD** Push Drive Probe Giron Geoprobe	**SHEET** 1 OF 2
DRILLER R. Skipper	**SAMPLING METHOD** Hammered Core	**DRILLING** START / FINISH
DRILLER R. Malpass		**TIME** 12:32 / **TIME** 13:15
GEOLOGIST C. Keith / RTI	**WEATHER** 90's - W5 - sunny	**DATE** 8-18-98 / **DATE** 8-18-98
DRILL RIG Concord 9200	**SURFACE CONDITIONS** unpaved grassed road shoulder	
ANGLE Vert. / **BEARING** —		
DATUM Land Surface / **ELEVATION** —	**COORDINATES** —	

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
0.0	0.0 to 4.0		#1	0.0-0.7 orange/tan silty sand		85%			Moderate			
1.0				0.7-1.8 - Dark brownish black organic VF to mostly silty sand								
2.0				1.8-3.2 Dark brownish black slightly moist organic VF to mostly silty sand								
3.0				3.2-3.8 - Moist to saturated dark brown highly organic VF to mostly silty sand								
4.0	4.0 to 8.0		#2	4.0-4.7 - Dark brownish black highly organic VF to mostly silty sand		82%			Moderate	^	4.0 - 12:32 - 8-18-98	
5.0				4.7-6.1 - Saturated light tan fine sand gradational into grey sand								
6.0				6.1-6.8 - grey clayey slightly saturated sand								
7.0				6.8-7.8 - Brown saturated med-F sand								
8.0												

BORING TERMINATED AT 12.0 FT BLS. LOGGED BY: C. Keith

COMMENTS:

☐ EXCAVATION

FIELD LITHOLOGIC LOG

SITE NAME AND LOCATION Perimeter Rd - onward WT CAF Assessment - 165' West of WT	PROJECT NO. 6448-019	BORING / EXCAVATION NO. WTB-3
DRILLING CONTRACTOR Skipper Well Drilling	DRILLING METHOD Push Drive Probe Circa Geoprobe	SHEET 2 OF 2
DRILLER R. Skipper	SAMPLING METHOD Hammered Core	DRILLING START TIME 12:32 / FINISH TIME 13:15
DRILLER R. Malpass		
GEOLOGIST C. Keith / RTI	WEATHER 90s - W5 - Sunny	DATE 8-18-98 / DATE 8-18-98
DRILL RIG Concord 9200	SURFACE CONDITIONS improved grassed road shoulder	
ANGLE Vert. / BEARING —		
DATUM Land Surface / ELEVATION —	COORDINATES —	

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
8.0 9.0	8.0	10.0	#3	8.0 - 9.3 - Grey Clayey to slightly clayey saturated F Sand		65%						
10.0 11.0	10.0	12.0	#4	10.0 - 11.6 - Slightly greenish grey sandy clay to clayey sand with wood particles		80%						
12.0												

BORING TERMINATED AT 12.0 FT BLS. LOGGED BY: C. Keith

COMMENTS:

☐ EXCAVATION

SITE NAME AND LOCATION C. 30' W of WT-4 WT C&F Assessment SW Ditch Bank-	PROJECT NO. 6448-019	BORING / EXCAVATION NO. WTB-4
DRILLING CONTRACTOR Skipper Well Drilling	DRILLING METHOD Push Drive Probe CIRCA Geo Probe	SHEET 1 OF 2
DRILLER R. Skipper	SAMPLING METHOD Hammered Core	DRILLING START TIME 14:00 / FINISH TIME 14:16
DRILLER R. Malpass		
GEOLOGIST C. Keith / RTI	WEATHER 90s - W5 - Sunny	START DATE 8-18-98 / FINISH DATE 8-18-98
DRILL RIG Concord 9200	SURFACE CONDITIONS improved grassed grade.	
ANGLE Vert. / BEARING —		
DATUM Land Surface / ELEVATION — 28.8' LAND	COORDINATES —	

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
0.0	0.0	4.0	#1	0.0 - 0.3 Brownish Black silty VF Sand		100%			hard			
				0.3 - 0.4 tan silt clay								
1.0				0.4 - 2.4 - Black organic F-VF silty sand gradational								
2.0												
3.0				2.4 - 4.0 Mocha Brown silty sand								
4.0	4.0	8.0	#2	4.0 - 4.8 - Brown silty VF Sand		100%						
5.0				4.8 - 5.8 yellowish tan moist silty to VF Sand							5.8 - 14:06 - 8-18-98	
6.0				5.8 - 6.5 - moist to wet yellowish tan silty to VF sand						↑		
				6.5 - 6.8 - Black saturated sandy silt with organic mtl								
7.0				6.8 - 7.8 - Brownish Gray F-VF Sand								
8.0				7.8 - 8.0 stiff tannish grey clay								

BORING TERMINATED AT 10.0 FT BLS. LOGGED BY: C. Keith

COMMENTS:

☐ EXCAVATION

SITE NAME AND LOCATION C 30' W of WT-4 WT C&F Assessment SW Ditch BANK	PROJECT NO. 6448-019	BORING / EXCAVATION NO. WTB-4
DRILLING CONTRACTOR Skipper Well Drilling	DRILLING METHOD Push Drive, Probe Circa Geoprobe	SHEET 2 OF 2
DRILLER R. Skipper	SAMPLING METHOD Hammered Core	DRILLING START TIME 14:00 / FINISH TIME 14:16
DRILLER R. Malpass		
GEOLOGIST C. Keith / RTE	WEATHER 90's - W-5 - Sunny	START DATE 8-18-98 / FINISH DATE 8-18-98
DRILL RIG Concord 9200	SURFACE CONDITIONS improved grassed grade.	
ANGLE Vert. / BEARING —		
DATUM Land Surface / ELEVATION —	COORDINATES —	

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
8.0				8.0-8.4 - Gray Sandy Clay								
9.0	8.0 to 10.0		#3	8.4-9.6 - Mottled Bluish grey stiff Clay		100%						
				9.6-10.0 Gray Sand/Clay								
10.0												

BORING TERMINATED AT 10.0 FT BLS. LOGGED BY: C. Keith

COMMENTS:

☑ BORING
☐ EXCAVATION

FIELD LITHOLOGIC LOG

SITE NAME AND LOCATION WT CAP Assessment - 30' N of WT6 on W side WT perimeter Rd	PROJECT NO. 6998-019	BORING / EXCAVATION NO. WTB-5
DRILLING CONTRACTOR Skipper Well Drilling	DRILLING METHOD Push Drive Probe Circa Geoprobe	SHEET 1 OF 27
DRILLER R. Skipper	SAMPLING METHOD Hammered Core	DRILLING START TIME 12:12 / FINISH TIME 12:22
DRILLER R. Malpass		
GEOLOGIST C. Keith / RTI	WEATHER 90's - W5 - Sunny	START DATE 8-19-98 / FINISH DATE 8-19-98
DRILL RIG Concord 9200	SURFACE CONDITIONS graded road shoulder	
ANGLE Vert.	BEARING	
DATUM Land Surface	ELEVATION	COORDINATES

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
0.0				0.0 - 0.7 - Med Brown Silty organic Sand								
				0.7 - 0.8 Tan/Gray Mottled Silty								
1.0	0.0	4.0	#1	0.8 - 1.5 - Dark Brown VF to Silty organic Sand		87%			Moderate			
				1.5 - 1.8 - Brownish Black VF to Silty organic Sand								
2.0				1.8 - 2.2 - Med light gray VF Sand moist								
3.0				2.2 - 3.5 - Dark Brown grades down to med. Brown moist to wet VF to Silty Sand								
4.0				4.0 - 4.3 Med DRK Brown VF Sand Bottom organic Silt Layer								
5.0				4.3 - 5.3 - Med Brown slightly clayey VF Sand Saturated								
	4.0	8.0	#2	5.3 - 5.9 Light Brown VF Sand		91%	Well Casing		Moderate		5.8 - 12:18 - 8-19-98 5.97 - 8-21-98	
6.0				5.9 - 7.0 Light Salt & pepper (white & Brown) down to med Brown F - VF Sand								
7.0				7.0 - 7.2 Brown Clayey VF Sand								
8.0												

BORING TERMINATED AT 8.0 FT BLS.   LOGGED BY: C. Keith

COMMENTS:

☐ EXCAVATION

FIELD LITHOLOGIC LOG

SITE NAME AND LOCATION site WT Pearmon Rd WT CAF Assessment - 30' N of WT-6 on W	PROJECT NO. 6498-019	BORING / EXCAVATION NO. WTB-5
DRILLING CONTRACTOR Skipper Well Drilling	DRILLING METHOD Push Drive Probe Girca Geoprobe	SHEET 2 OF 2
DRILLER R. Skipper	SAMPLING METHOD Hammered Core	DRILLING START TIME 12:12 FINISH TIME 12:22
DRILLER R. Malpass		
GEOLOGIST C. Keith / RTI	WEATHER 90's - WS - sunny	START DATE 8-19-98 FINISH DATE 8-19-98
DRILL RIG Concord 9200	SURFACE CONDITIONS graded road shoulder	
ANGLE Vert. / BEARING —		
DATUM Land Surface / ELEVATION —	COORDINATES —	

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
8.0				8.0 - 8.45 Brown VF Sand & Clay								
	9.0	10.0	#3	8.45 - 8.6 Grayish white VF Sand					Moderate			
9.0				8.6 - 9.2 Brownish gray CLAY		60%						
10.0												

BORING TERMINATED AT 10.0 FT BLS.

LOGGED BY: C. Keith

COMMENTS:

☑ BORING
☐ EXCAVATION

FIELD LITHOLOGIC LOG

SITE NAME AND LOCATION WT CAF Assessment - 210' N of Channel Rd	PROJECT NO. 6998-019	BORING / EXCAVATION NO. WTB-6
DRILLING CONTRACTOR Skipper Well Drilling	DRILLING METHOD Push Drive Probe CIRCA Geoprobe	SHEET 1 OF 2
DRILLER R. Skipper	SAMPLING METHOD Hammered Core	DRILLING START TIME 13:32 / FINISH TIME 13:53
DRILLER R. Malpass		
GEOLOGIST C. Keith / RTI	WEATHER 90's - W-5 - Sunny	START DATE 8-19-98 / FINISH DATE 8-19-98
DRILL RIG Concord 9200	SURFACE CONDITIONS unimproved grassed AREA	
ANGLE Vert. / BEARING —		
DATUM Land Surface / ELEVATION —	COORDINATES —	

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
0.0	0.0 to 4.0		#1	0.0-1.0 DARK Brown VF to Silty organic Sand		100%			Moderate			
1.0				1.0-1.2 - Brownish Grey stiff Clay								
				1.2-2.0 DARK Brown VF to Silty ORGAnic sand with sparse Clay stringers								
2.0				2.0-2.4 - DARK Brown stiff Clay/Sand								
				2.4-2.7 Light tannish grey clay								
3.0				2.7-4.0 - very DARK BLACK slightly sandy silt - slightly moist								
4.0 5.0	4.0 to 8.0		#2	4.0-6.0 - dark Brown Silty sand - coarsens & lightens down		100%	well casing		difficult			
6.0				6.0-6.6 - Brownish/Grey slightly saturated VF Sand							6.0 - 13:38 - 8-19-98 8.8 - 8-21-98	
7.0 8.0				6.6-8.0 - Brown/reddish VF Sand								

BORING TERMINATED AT 12.0 FT BLS. LOGGED BY: C. Keith

COMMENTS:

☑ BORING
☐ EXCAVATION

FIELD LITHOLOGIC LOG

SITE NAME AND LOCATION WT CAF Assessment - 210' N of Channel Rd	PROJECT NO. 6448-019	BORING / EXCAVATION NO. WTB-6
DRILLING CONTRACTOR Skipper Well Drilling	DRILLING METHOD Push Drive Probe CIRCA Geo Probe	SHEET 2 OF 2
DRILLER R. Skipper	SAMPLING METHOD Hammered Core	DRILLING START TIME 13:32 / FINISH TIME 13:53
DRILLER R. Malpass		
GEOLOGIST C. Keith / RTI	WEATHER 90's - WS - Sunny	START DATE 8-19-98 / FINISH DATE 8-19-98
DRILL RIG Concord 9200	SURFACE CONDITIONS unimproved grassed area.	
ANGLE Vert. / BEARING —		
DATUM Land Surface / ELEVATION —	COORDINATES —	

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
8.0	8.0 to 10.0		#3	8.0 - 8.5 - Reddish Brown VF Sand		55%			moderate			
				8.5-8.7 Black Clayey silty VF Sand								
9.0				9.7 - 9.1 - Gray Clay/Sand								
10.0	10.0 to 12.0		#4	10.0 - 10.4 - Brown saturated F-VF Sand		90%			moderate			
11.0				10.4 - 11.2 - Gradational gray VF Sand to Sandy Clay								
				11.2 - 11.6 = Mottled Bluish / Grey Clay								
12.0												

BORING TERMINATED AT 12.0 FT BLS. LOGGED BY: C. Keith

COMMENTS:

☑ BORING
☐ EXCAVATION

FIELD LITHOLOGIC LOG

SITE NAME AND LOCATION WT CAF Assessment - 380' west of WB-6	PROJECT NO. 6498-019	BORING / EXCAVATION NO. WTB-7
DRILLING CONTRACTOR Skipper Well Drilling	DRILLING METHOD Push Drive Probe CIRCA Geoprobe	SHEET 1 OF 2
DRILLER R. Skipper	SAMPLING METHOD Hammered Core	DRILLING START TIME 08:00 / FINISH TIME 09:30
DRILLER R. Malpass		
GEOLOGIST C Keith / RTI	WEATHER 80s - NE5 - sunny	START DATE 8-20-98 / FINISH DATE 8-20-98
DRILL RIG Concord 9200	SURFACE CONDITIONS improved road grade shoulder	
ANGLE Vert. / BEARING —		
DATUM Land Surface / ELEVATION —	COORDINATES —	

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
0.0	0.0	4.0	#1	0.0 - 0.7 - Light Brown VF-F Sand with organics		100%			Hard			
1.0				0.7 - 1.6 - Dark grey to dark Black VF silty organic Sand								
2.0				1.6 - 2.2 - mottled tan/orangish Brown VF Sand								
				2.2 - 3.0 - mottled light tan & orange VF Sand								
3.0				3.0 - 4.0 - med Brown moist VF to silty Sand								
4.0	4.0	8.0	#2	4.0 - 4.4 - med Brown VF to silty Sand		100%	Well casing		Hard			
				4.4 - 4.6 Black silty organic Sand								
5.0 6.0 7.0				4.6 - 7.6 - mottled light tan & Brown VF moist Sand - Lightens Down							7.0 - 08:15 - 8-20-98 7.13 - 8-21-98	Slightly moist
8.0				7.6 - 8.0 med Brown to Black VF Sand with organics								

BORING TERMINATED AT 14.0 FT BLS. LOGGED BY: C. Keith / RTI

COMMENTS:

☑ BORING
☐ EXCAVATION

FIELD LITHOLOGIC LOG

SITE NAME AND LOCATION WT CAF Assessment - 380' west of WTB-6	PROJECT NO. 6448-019	BORING / EXCAVATION NO. WTB-7
DRILLING CONTRACTOR Skippen Well Drilling	DRILLING METHOD Push Drive Probe circa Geoprobe	SHEET 2 OF 2
DRILLER R. Skippen	SAMPLING METHOD Hammered Core	DRILLING START TIME 08:00 / FINISH TIME 09:30
DRILLER R. Malpass		
GEOLOGIST C. Keith / RTI	WEATHER 80's - NES - Sunny	START DATE 8-20-98 / FINISH DATE 8-20-98
DRILL RIG Concord 9200	SURFACE CONDITIONS improved road grade shoulder	
ANGLE Vert.	BEARING —	
DATUM Land Surface	ELEVATION —	COORDINATES —

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
8.0	8.0	to 10.0	#3	8.0 - 9.3 - gray clayey VF sand		65%			Moderate			
9.0												
10.0	10.0	to 12.0	#4	10.0 - 11.0 - gray slightly clayey VF sand		50%			Moderate			
11.0												
12.0	12.0	to 14.0	#5	12.0 to 13.3 Light greenish gray sandy clay		65%			Hard			
13.0												
14.0												

BORING TERMINATED AT 14.0 FT BLS. LOGGED BY: C. Keith

COMMENTS:

☑ BORING
☐ EXCAVATION

FIELD LITHOLOGIC LOG

SITE NAME AND LOCATION 120' East of WT CaF Assessment Cw-6ed woods Edge	PROJECT NO. 6448-018	BORING / EXCAVATION NO. WTB-8
DRILLING CONTRACTOR Skipper Well Drilling	DRILLING METHOD Push Drive Probe Circa GeoProbe	SHEET 1 OF 2
DRILLER R. Skipper	SAMPLING METHOD Hammered Core	DRILLING START TIME 11:02 / FINISH TIME 12:26
DRILLER R. Malpass		
GEOLOGIST C. Keith / RTI	WEATHER 80's - NES - Sunny	START DATE 8-20-98 / FINISH DATE 8-20-98
DRILL RIG Concord 9200	SURFACE CONDITIONS improved road grade shoulder	
ANGLE Vert. / BEARING —		
DATUM Land Surface / ELEVATION —	COORDINATES —	

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
0.0	0.0 to 4.0		#1	0.0 - 0.4 Red light + Brown sandy organic soil		100%			EASY			
1.0				0.4 - 2.0 - Brownish/Black mostly silty VF organic sand								
2.0 3.0				2.0 - 4.0 dark Brown VF to silty VF sand - slightly moist with sparse clay at Bottom								
4.0	4.0 to 8.0		#2	4.0 - 4.3 - Brown VF sand		75%	WELL CASING		EASY			
5.0				4.3 - 5.1 - Greyish/tan clayey VF sand								
				5.1 - 6.0 - Reddish/Brown moist VF sand								
6.0 7.0 8.0				6.0 - 8.0 - moist garnet Red/Brown VF sand								

BORING TERMINATED AT 14.0 FT BLS. LOGGED BY: C. Keith / RTI

COMMENTS:

☑ BORING
☐ EXCAVATION

FIELD LITHOLOGIC LOG

SITE NAME AND LOCATION WT C&F Assessment - 120' East of CW-6 Rd woods edge	PROJECT NO. 6948-019	BORING / EXCAVATION NO. WTB-8
DRILLING CONTRACTOR Skipper Well Drilling	DRILLING METHOD Push Drive Probe Circa Geoprobe	SHEET 2 of 2
DRILLER R. Skipper	SAMPLING METHOD Hammered Probe	DRILLING START TIME 11:02 / FINISH TIME 11:26
DRILLER R. Malpass		
GEOLOGIST C. Keith/RTI	WEATHER 80's - NE5 - sunny	START DATE 8-20-98 / FINISH DATE 8-20-98
DRILL RIG Concord - 9200	SURFACE CONDITIONS improved Road grade shoulder	
ANGLE Vert.	BEARING —	
DATUM Land Surface	ELEVATION —	COORDINATES —

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
8.0 9.0	8.0 to 10.0		#3	8.0 - 11.0 - moist to saturated garnet red/Brown VF sand		90%			Easy	↓	11:13 - 8/20/98 9.0 BLS	8.98 - 8-21-98
10.0 11.0	10.0 to 12.0		#4	10.0 - 11.0 - saturated garnet red/Brown VF sand 11.0 - 11.5 - Brown slightly sandy clay		75%			Moderate			
12.0 13.0	12.0 to 14.0		#5	12.0 - 12.5 greyish Brown saturated clayey sand 12.5 - 12.8 Dk greyish Brown sandy clay 12.8 - 13.2 - Light greyish Brown VF sand - slightly clayey 13.2 - 13.7 - Bluish grey clay		90%			Moderate			
14.0												

BORING TERMINATED AT 14.0 FT BLS. LOGGED BY: C. Keith

COMMENTS:

☑ BORING
☐ EXCAVATION

FIELD LITHOLOGIC LOG

SITE NAME AND LOCATION WT N Access Rd WT C&F Assessment- 45' N of	PROJECT NO. 6448-019	BORING / EXCAVATION NO WTB-9
DRILLING CONTRACTOR Skipper Well Drilling	DRILLING METHOD Push Drive Probe Circa GeoProbe	SHEET 1 OF 2
DRILLER R. Skipper	SAMPLING METHOD Hammered Core	DRILLING START TIME 10:00 / FINISH TIME 10:15
DRILLER R. Malpass		
GEOLOGIST C. Keith / RTI	WEATHER 80's - NE5 - Sunny	DATE 8-20-98 / DATE 8-20-98
DRILL RIG Conrad 9200	SURFACE CONDITIONS improved road grade shoulder	
ANGLE Vert. / BEARING —		
DATUM Land Surface / ELEVATION —	COORDINATES —	

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
0.0 1.0 2.0	0.0 to 4.0		#1	0.0 - 2.4 dk Brown mottled mostly silty VF Sand with tan pockets - organic		100%			Easy			
3.0				2.4 - 4.0 - Black mostly silty VF Sand with white quartz grains								
4.0 5.0	4.0 to 8.0		#2	4.0 to 6.0 - dk Brown moist very silty VF Sand			Well casing					
6.0				6.0 - 6.8 Light Brown slightly clayey moist VF Sand					Easy			
7.0 8.0				6.8 - 8.0 - dk Brown organic silty moist VF Sand with Large wood particles								

BORING TERMINATED AT 12.0 FT BLS. LOGGED BY: C. Keith

COMMENTS:

☑ BORING
☐ EXCAVATION

FIELD LITHOLOGIC LOG

SITE NAME AND LOCATION WT N Access Rd WT CAF Assessment- 45'N of	PROJECT NO. 6948-019	BORING / EXCAVATION NO WTB-9
DRILLING CONTRACTOR Skipper Well Drilling	DRILLING METHOD Push Drive Probe Circa GeoProbe	SHEET 2 OF 2
DRILLER R. Skipper	SAMPLING METHOD Hammered Core	DRILLING START TIME 10:00 FINISH TIME 10:15
DRILLER R. Malpass		
GEOLOGIST C. Keith / RTI	WEATHER 90's - NE5 - Sunny	START DATE 8-20-98 FINISH DATE 8-21-98
DRILL RIG Concord 9200	SURFACE CONDITIONS improved Road grade Shoulder	
ANGLE Vert.	BEARING —	
DATUM Land Surface	ELEVATION —	COORDINATES —

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
8.0	8.0 to 10.0		#3	8.0 - 9.5 - Moist Brownish / Red VF Sand	∴	75%			Easy		10.4 BLS 10:15 / 8-20-98	
9.0												
10.0	10.0 to 12.0		#4	10.0 - 10.4 - Brownish / Black Moist VF Sand	∴	90%		—	Easy	↑	9.94 - 8-21-98	
				10.4 - 11.5 - Saturated - wood mass with sparse grey clay veins	V							
11.0												
				11.5 - 11.8 - greenish grey stiff Clay	≡							
12.0												

BORING TERMINATED AT 12.0 FT BLS. LOGGED BY: C. Keith

COMMENTS:

FIELD LITHOLOGIC LOG

☐ EXCAVATION

SITE NAME AND LOCATION Between E: W Lagoons WT CAF Assessment - on N End of WT Dikes	**PROJECT NO.** 6448-019	**BORING / EXCAVATION NO.** WTB-10
DRILLING CONTRACTOR Skippen Well Drilling	**DRILLING METHOD** Push Drive Probe / CIRCA Geoprobe	**SHEET** 1 OF 3
DRILLER R. Skippen	**SAMPLING METHOD** Hammered Core	**DRILLING** START TIME 14:13 / FINISH TIME 15:10
DRILLER P. Skippen		
GEOLOGIST C. Keith / RTE	**WEATHER** 80's – Windy - Storm Approaching From NW	START DATE 9-8-98 / FINISH DATE 9-8-98
DRILL RIG Concord 9200	**SURFACE CONDITIONS** on Asphalt dike fill	
ANGLE Vert.	**BEARING** —	
DATUM Asphalt ~~Land~~ Surface	**ELEVATION** —	**COORDINATES** —

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
0.0 – 4.0	0.0	4.0	#1	0.0 – 4.0 – mottled whitish orangish Brown tacky Clayey Borrow pit Sand		100%			moderate			
4.0 – 8.0	4.0	8.0	#2	4.0 - 8.0 - Mottled vF whitish/orangish/Brown tacky clayey Borrow pit Sand with Bottom 0.5 Brownish Black Silt			Well casing continued to 12.9' BLS		Difficult			

BORING TERMINATED AT 20.0 FT BLS.

LOGGED BY: C. Keith / RTE

COMMENTS:

☐ EXCAVATION

SITE NAME AND LOCATION Between E & W Lagoons WTCAF Assessment - N end of WT Dikes	PROJECT NO. 6448-019	BORING / EXCAVATION NO. WTB-10
DRILLING CONTRACTOR Skipper Well Drilling	DRILLING METHOD Push Drive Probe Quick geoprobe	SHEET 2 of 3
DRILLER R. Skipper	SAMPLING METHOD Hammered Core	DRILLING START TIME 14:13 / FINISH TIME 15:10
DRILLER P. Skipper		
GEOLOGIST C. Keith / J. Green / RTI	WEATHER 80's Windy - Storm almost here - From O	START DATE 9-8-98 / FINISH DATE 9-8-98
DRILL RIG Concord 9200	SURFACE CONDITIONS on asphalt dike fill	
ANGLE Vert. / BEARING —		
DATUM Asphalt Surface / ELEVATION —	COORDINATES —	

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
8.0 9.0	8.0 to 12.0		#3	8.0 - 10.0 - moist Borrow pitfill - VF mottled whitish/orangish/Brown clayey sand		100%						
10.0				10.0 - 11.0 - Black organic silt with gray clay stringers			Well casing 12.9' BLS				10.99 BLS - 9-10-98 12.9 BLS - 14:99 - 9-8-98	
11.0				11.0 - 11.2 . Brown/tan moist VF silty sand								
				11.2 - 12.0 - Black organic silt								
12.0	12.0 to 16.0		#4	12.0 - 12.9 - Moist Gray VF silty clayey sand		100%						
13.0				12.9 - 13.2 Saturated VF Brownish Gray Clayey silty sand								
				13.2 - 14.0 - moist Grayish Brown silty VF sand								
14.0				14.0 - 14.8 - Olive Brown saturated VF sand								
15.0 16.0				14.8 - 16.0 - Dark Brown saturated organic clayey silt								

BORING TERMINATED AT 20.0 FT BLS. LOGGED BY: C. Keith

COMMENTS:

☐ EXCAVATION

SITE NAME AND LOCATION Between E: W Lagoons WT CAF Assessment - on N end of WT Dikes	PROJECT NO. 6448-019	BORING / EXCAVATION NO. WTB-10
DRILLING CONTRACTOR Skipper Well Drilling	DRILLING METHOD Push Drive Probe Circa Geoprobe	SHEET 3 OF 3
DRILLER R Skipper	SAMPLING METHOD Hammered Core	DRILLING START TIME 14:13 FINISH TIME 15:10
DRILLER P. Skipper		
GEOLOGIST C. Keith / J. Green / RTI	WEATHER 80's - windy - storm approaching	START DATE 9-8-98 FINISH DATE 9-8-98
DRILL RIG Concord 9200	SURFACE CONDITIONS on asphalt dike fill	
ANGLE Vert. / BEARING —		
DATUM Asphalt Surface / ELEVATION —	COORDINATES —	

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
16.0	16.0	18.0	#5	16.0 - 16.3 - Damp Grey Silty VF Sand		90%						
				16.3 - 16.5 - Brownish Grey Slightly Sandy Stiff Clay								
				16.5 - 16.8 Grey VF Silty Clayey Sand								
17.0				16.8 - 17.4 - Dark Grey Stiff Clay with Orange VF Sand Stringers								
18.0	18.0	20.0	#6	18.0 - 18.2 - Moist Med Brown VF Sand		90%						
				18.2 - 19.3 - Moist silty VF Sand with Bottom 0.3 stiff gray clay								
19.0				19.3 - 19.8 - Grey silty stiff Clay								
20.0												

BORING TERMINATED AT 20.0 FT BLS. LOGGED BY: C. Keith

COMMENTS:

FIELD LITHOLOGIC LOG

☑ BORING
☐ EXCAVATION

SITE NAME AND LOCATION WT CAF Assessment - Behind NW End of WT Bldg Facility	PROJECT NO. 6498-019	BORING / EXCAVATION NO. WTB-11
DRILLING CONTRACTOR Skipper Well Drilling	DRILLING METHOD Push Drive Probe CIRCA Geoprobe	SHEET 1 OF 2
DRILLER R. Skipper	SAMPLING METHOD Hammered Core	DRILLING START TIME ~~11:13~~ 13:17 · FINISH TIME ~~09:32~~ 13:
DRILLER P. Skipper		
GEOLOGIST C. Keith/RTI / J. Green	WEATHER Hot- 80-90 - Humid - SW 5	START DATE 9-2-98 · FINISH DATE 9-2-98
DRILL RIG Concord 9200	SURFACE CONDITIONS improved Asphalt grade.	
ANGLE Vert.	BEARING —	
DATUM Asphalt/Land Surface	ELEVATION —	COORDINATES —

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
0.0	0.0 ↓	4.0	H1	0.0-0.3 Med Brown Fill Sand & Gravel (3" under Asphalt)		63%			moderate to difficult			
				0.3 - 2.5 - Mottled Brown/orange/tan VF Silty Sand								
1.0												
2.0												
3.0												
4.0	4.0 to	8.0	H2	4.0- 4.4- Moist Brown VF Sand		98%			moderate		4.5 BLS- 13:28 9-2-98	
				4.4-5.5- Saturated Brown F-VF Sand								
5.0				5.5-6.2- Saturated orangish/Brown VF Silty Sand								
6.0				6.2-6.8 - Moist Greyish/Brown VF Sand with Black Stain Interval								
				6.8-7.0- Dk Gray VF Silty Sand								
7.0				7.0-7.5 - yellowish/Brown VF Silty Sand								
8.0												

BORING TERMINATED AT 12.0 FT BLS.
LOGGED BY: C. Keith
COMMENTS:

☑ BORING
☐ EXCAVATION

FIELD LITHOLOGIC LOG

SITE NAME AND LOCATION WT Bldg Facility AT WT-7 WT C&F Assessment - Behind NW End of	PROJECT NO. 6448	BORING / EXCAVATION NO. WTB-11
DRILLING CONTRACTOR Skippen Well Drilling	DRILLING METHOD Push Drive Probe circa Geoprobe	SHEET 2 OF 2
DRILLER R. Skippen	SAMPLING METHOD Hammered Core	DRILLING START TIME: ~~[illegible]~~ 8:17 FINISH TIME: ~~09:32~~ 13:52
DRILLER P. Skippen		
GEOLOGIST C. Keith / J. Green - RTI	WEATHER Hot - 80's - 90's - Humid - SWS	START DATE 9.2.98 FINISH DATE 9.2.98
DRILL RIG Concord 9200	SURFACE CONDITIONS impaired asphalt grade	
ANGLE Vert.	BEARING —	
DATUM Asphalt Land Surface	ELEVATION —	COORDINATES —

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
8.0	8.0 to 12.0		#3	8.0 - 8.8 - Brownish/orange VF silty sand		100%			D.Flack			
9.0				8.8 - 9.2 Mottled Brown VF sand with Black stain interval								
				9.2 - 10.0 - Saturated mottled dark grey to grey VF silty sand								
10.0				10.0 - 12.0 - Steel grey sandy clay with organic material								
11.0												
12.0												

BORING TERMINATED AT 12.0 FT BLS. LOGGED BY: C. Keith

COMMENTS:

☑ BORING
☐ EXCAVATION

FIELD LITHOLOGIC LOG

SITE NAME AND LOCATION 20' W of WT Access Rd swale WT CAF Assessment - 20' S of WT staging Rd.	PROJECT NO. 6449-019	BORING / EXCAVATION NO. WTB-12
DRILLING CONTRACTOR Skippen Well Drilling	DRILLING METHOD Push Drive Probe CIRCA Geoprobe	SHEET 1 OF 2
DRILLER R. Skippen	SAMPLING METHOD Hammered Core	DRILLING START TIME 09:50 / FINISH TIME 10:18
DRILLER P. Skippen		
GEOLOGIST C. Keith/RTE	WEATHER Hot - 80's - Humid - SE 5-10	START DATE 8-31-98 / FINISH DATE 8-31-98
DRILL RIG Concord 9200	SURFACE CONDITIONS Improved Grassed Grade.	
ANGLE Vert.	BEARING —	
DATUM Land Surface	ELEVATION —	COORDINATES —

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
0.0	0.0	4.0	#1	0.0-0.2 Tan/Brown F-VF Sand with organic material		100%			Easy			
				0.2-2.8 _ Dark Brownish Black Sandy organic Silt with wood particles								
1.0												
2.0												
				2.8-3.0 Gray Clay & Black Silt								
3.0				3.0-3.6 – Brown VF Sandy Clay								
				3.6-4.0 – Dark Brown VF Sandy Silt with wood particles down to salt & pepper								
4.0	4.0	8.0	#2	4.0-4.5 Salt & pepper gray F-VF Sand & Brown F-VF Sand gradational to		100%	Well Casing 6.5' BLS		Moderate	4.85' BLS - 9-2-98	4.0' - 09:57 - 8-31-98	
				4.5-8.0 - Brownish Black organic VF Sandy Silt moist to saturated at bottom 7.0-8.0								
5.0												
6.0												
7.0												
8.0												

BORING TERMINATED AT 14.0 FT BLS. LOGGED BY: C. Keith/RTE

COMMENTS:

☑ BORING
☐ EXCAVATION

FIELD LITHOLOGIC LOG

SITE NAME AND LOCATION 30' W of WT Access Rd swale WT CAF Assessment - 20'S of WT Staging Rd	PROJECT NO. 6448-019	BORING / EXCAVATION NO. WTB-12
DRILLING CONTRACTOR Skipper Well Drilling	DRILLING METHOD Push Drive Probe CIRCA Geoprobe	SHEET 2 OF 2
DRILLER R. Skipper	SAMPLING METHOD Hammered Core	DRILLING: START TIME 09:50 / FINISH TIME 10:18
DRILLER P. Skipper		
GEOLOGIST C. Keith / RTI	WEATHER Hot-80's - Humid - SE-5-10	START DATE 8-31-98 / FINISH DATE 8-31-98
DRILL RIG Concord 9200	SURFACE CONDITIONS improved grassed grade	
ANGLE Vert / BEARING —		
DATUM Land Surface / ELEVATION —	COORDINATES —	

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
8.0	8.0 to ~~[illegible]~~ 12.0		#3	8.0-9.0- Dark Brown F-VF Sand Saturated		75%			moderate			
9.0				9.0-9.8- med tan/Brown Fine Sand								
10.0				9.8-10.5- Light greenish grey Clayey VF Sand								
				10.5-11.0 whitish grey VF Sand Fe/MD								
11.0												
12.0	12.0 to 14.0		#4	12.0-13.3- Saturated dark Brown VF Sand		65%			moderate			
13.0												
14.0												

BORING TERMINATED AT 14.0 FT BLS.   LOGGED BY: C. Keith/RTI

COMMENTS:

FIELD LITHOLOGIC LOG

☑ BORING
☐ EXCAVATION

SITE NAME AND LOCATION WTCaF Assessment - 5' N of WT-9	PROJECT NO. 6448-019	BORING / EXCAVATION NO. WTB-13
DRILLING CONTRACTOR Skipper Well Drilling	DRILLING METHOD Push Drive Probe CIRCA Geoprobe	SHEET 1 of 2
DRILLER R. Skipper	SAMPLING METHOD Hammered Core	DRILLING START TIME 10:59 / FINISH TIME 11:29
DRILLER P. Skipper	WEATHER ~~[illegible] to [illegible]~~e Humid - 80's - SE - 5 - 15	START DATE 8-31-98 / FINISH DATE 8-31-98
GEOLOGIST C. Keith / RTI / J. Green		
DRILL RIG Concord 9200	SURFACE CONDITIONS improved grassed grade	
ANGLE Vert. / BEARING —		
DATUM Land Surface / ELEVATION —	COORDINATES —	

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
0.0	0.0 to 4.0		#1	0.0-1.3 - Mottled Brown : tan VF organic Sand		83%			Easy			
1.0				1.3-2.2 - Mottled Brown : tan clayey VF Sand with organic material								
2.0				2.2-2.6 Salt : pepper VF to Silty Sand								
3.0				2.6-3.3 - Mottled orange : tan VF Sand								
4.0	4.0 to 8.0		#2	4.0-4.2 Moist Light tan with orange VF Sand		75%	Well casing continued to 10.9' BLS		Moderate		6.59' BLS - 9-8-98 9.0' BLS - 9-1-98	
5.0				4.2-5.6 - Orange VF Sand gradational down into								
6.0				5.6-6.5 - Moist Light tan VF Sand								
7.0				6.5-7.0 - Tannish orange VF to Silty Sand								
8.0												

BORING TERMINATED AT 16.0 FT BLS. LOGGED BY: C. Keith / RTI

COMMENTS:

☑ BORING
☐ EXCAVATION

FIELD LITHOLOGIC LOG

SITE NAME AND LOCATION WT CAF Assessment - 5' N of WT-9	PROJECT NO. 6448-019	BORING / EXCAVATION NO. WTB-13
DRILLING CONTRACTOR Skipper Well Drilling	DRILLING METHOD Push Drive Probe CIRCA Geoprobe	SHEET 2 OF 2
DRILLER R. Skipper	SAMPLING METHOD Hammered Core	DRILLING START TIME 10:59 / FINISH TIME 11:29
DRILLER R. Skipper		
GEOLOGIST C. Keith / J. Green / RTI	WEATHER ~~[illegible]~~ Humid - 80s - SE - 5-15	START DATE 8-31-98 / FINISH DATE 8-31-98
DRILL RIG Concord 9200	SURFACE CONDITIONS improved grassed grade	
ANGLE Vert.	BEARING —	
DATUM Land Surface	ELEVATION —	COORDINATES —

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
8.0	8.0	12.0	#3	8.0 - 9.5 - Saturated Brown VF Sand gradational into		100%	Well Casing 10.9' BLS		Moderate			
9.0				9.5 - 9.1 - Med tan F-VF Sand gradational into								
10.0				9.1 - 10.9 - Mottled orange & tan F-VF Sand gradational into								
11.0				10.9 - 12.0 - Light orangish tan clayey silty VF Sand with deep orange oxidized stringers								
12.0	12.0	14.0	#4	12.0 - 13.3 - Grayish tan VF to silty sand with orange oxidized intervals		65%			Moderate			
13.0												
14.0	14.0	16.0	#5	14.0 - 14.8 Mottled orange & tan F-VF Sand saturated		100%			Moderate			
15.0				14.8 - 15.2 - Mottled orange & tan clayey VF Sand								
16.0				15.2 - 16.0 - Med tan to pink mottled slightly sandy sticky clay with oxidized intervals								

BORING TERMINATED AT 16.0 FT BLS.   LOGGED BY: C. Keith

COMMENTS:

FIELD LITHOLOGIC LOG

☐ EXCAVATION 60' N of WT main Rd

SITE NAME AND LOCATION 90' East of WTB-15 WT CAF Assessment - SE of WT plant	PROJECT NO. 6448-019	BORING / EXCAVATION NO. WTB-14
DRILLING CONTRACTOR Skipper Well Drilling	DRILLING METHOD Push Drive Probe Circa Geoprobe	SHEET 1 OF 2
DRILLER R. Skipper	SAMPLING METHOD Hammered Core	DRILLING START TIME 14:40 / FINISH TIME 15:09
DRILLER P. Skipper		
GEOLOGIST C. Keith / RTI	WEATHER 90's - SW - 5-10	START DATE 9-1-98 / FINISH DATE 9-1-98
DRILL RIG Concord 9200	SURFACE CONDITIONS improved grassed grade	
ANGLE Vert	BEARING —	
DATUM Land Surface	ELEVATION —	COORDINATES —

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
0.0	0.0 to 4.0		#1	0.0 – 0.6 – Brownish/Black organic VF silty sand		100%			Difficult			
				0.6 – 1.0 – Grey VF sand								
1.0				1.0 – 1.4 – Med. Brown VF silty sand								
				1.4 - 2.0 – Moist to saturated orange VF silty sand								
2.0				2.0 – 4.0 – Orange VF clayey sand								
3.0												
4.0	4.0 to 8.0		#2	4.0 - 4.3 - Orange VF clayey sand		73%	~~Continued to~~ 8.75' BLS		Moderate		6.65' BLS - 9-2-98	
				4.2-4.3 Dark Black organic silt								
				4.3 - 4.9 - Orangish tan VF sand								
5.0				4.9 - 5.5 - Orangish tan VF sand								
6.0				5.5 - 6.9 - Moist light tan & black mottled VF organic sand								
7.0												
8.0												

BORING TERMINATED AT 16.0 FT BLS. LOGGED BY: C. Keith / RTI

COMMENTS:

FIELD LITHOLOGIC LOG

☐ EXCAVATION 90' East of WTB-16

SITE NAME AND LOCATION of WT main Rd WT C&F Assessment - SE of WT Plant - 60' N	PROJECT NO. 6448-019	BORING / EXCAVATION NO. WTB-17
DRILLING CONTRACTOR Skipper Well Drilling	DRILLING METHOD Push Drive Probe Circa Geoprobe	SHEET 2 OF 2
DRILLER R. Skipper	SAMPLING METHOD Hammered Core	DRILLING START TIME 14:40 / FINISH TIME 15:09
DRILLER P. Skipper		
GEOLOGIST C. Keith / RTI	WEATHER 90's - SW - 5-10	START DATE 9-1-98 / FINISH DATE 9-1-98
DRILL RIG Concord 9200	SURFACE CONDITIONS improved grassed grade.	
ANGLE Vert. / BEARING —		
DATUM Land Surface / ELEVATION —	COORDINATES —	

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
8.0	8.0	12.0	#3	8.0-10.0 - Saturated greyish tan med to fine Sand		100%	8.75 BLS w/1 Casing		Moderate		9.0 - BLS - 14:54 9-1-98 6.68 - BLS - 9-2-98	
10.0				10.0 - 12.0 - Saturated mottled very light whitish/tan VF Sand with orange oxidation stringers & black organic stringers								
12.0	12.0	14.0	#4	~~12.0-12.2 saturated orangish/white slightly silty sand~~		60%						
				12.2 - 13.2 - Moist mottled orange & grey VF silty clayey sand								
14.0	14.0	16.0	#5	14.0 - 14.9 - Saturated orange silty sand		100%						
15.0				14.9 - 15.3 moist light grey silty sand								
				15.3 - 16.0 - Grey gradational down to orange slightly sandy clay								
16.0												

BORING TERMINATED AT 16.0 FT BLS. LOGGED BY: C. Keith / RTI

COMMENTS:

FIELD LITHOLOGIC LOG

☐ EXCAVATION 120' East of CW 7A Rd

SITE NAME AND LOCATION 60' N of CW-7A & WT CAF Assessment - SE of WT Bldgs	PROJECT NO. 6448-019	BORING / EXCAVATION NO. WTB-15
DRILLING CONTRACTOR Skipper Well Drilling	DRILLING METHOD Push Drive Probe Circa Geoprobe	SHEET 1 OF 3
DRILLER R. Skipper	SAMPLING METHOD Hammered Core	DRILLING START TIME 12:45 / FINISH TIME 13:28
DRILLER P. Skipper		
GEOLOGIST C. Keith / RTI / J. Green	WEATHER Hot - 90's - Humid - SW 5-10	START DATE 9-1-98 / FINISH DATE 9-1-98
DRILL RIG Concord 9200	SURFACE CONDITIONS improved grassed grade.	
ANGLE Vert. / BEARING —		
DATUM Land Surface / ELEVATION —	COORDINATES —	

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
0.0	0.0	4.0	#1	0.0-0.9 Blackish Brown VF Sandy Silt with organic material		90%			Easy			
1.0				0.9-1.2 Orange/Brown VF Sand								
				1.2-1.6. moist Dark Gray VF Sand								
2.0				1.6-2.1 Orangish Brown VF sandy clayey silt								
				2.1-2.4 yellowish tan VF Sandy Clayey Silt								
3.0				2.4-3.2 yellowish/tan stiff clay								
4.0	4.0	8.0	#2	4.0-4.2 yellowish tan moist clayey sand		98%	Continued to 17' BLS		Moderate		5.83 BLS- 9-2-98 8.0 BLS- 13:00- 9-1-98	
5.0				4.2-5.1- Orange VF Sand								
				5.1-5.6- tan VF Sand								
6.0				5.6-6.3- mottled orange & tan VF Sand								
7.0				6.3-7.1 whitish tan VF moist sand								
8.0												

BORING TERMINATED AT 18.0 FT BLS.   LOGGED BY: C. Keith / RTI

COMMENTS:

☑ BORING
☐ EXCAVATION

FIELD LITHOLOGIC LOG

SITE NAME AND LOCATION 60' N of CW-7A 120' East of CW-7A Rd WT CAF Assessment - SE of WT Bldgs	PROJECT NO. 6448-019	BORING / EXCAVATION NO. WTB-15
DRILLING CONTRACTOR Skipper Well Drilling	DRILLING METHOD Push Drive Probe Arien Geoprobe	SHEET 2 OF 3
DRILLER R. Skipper	SAMPLING METHOD Hammered Core	DRILLING START TIME 12:45 / FINISH TIME 13:28
DRILLER P. Skipper		
GEOLOGIST C. Keith / J. Green - RTE	WEATHER Hot - 90's - Humid - SW 5-10	DATE 9-1-98 / DATE 9-1-98
DRILL RIG Concord 9200	SURFACE CONDITIONS improved grassed grade.	
ANGLE Vert. / BEARING —		
DATUM Land Surface / ELEVATION —	COORDINATES —	

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
8.0	8.0	12.0	#3	8.0-8.4 - Soupy VF to silty yellowish tan sand		100%			Moderate			
9.0				8.4-10.4 Saturated light tan F-VF sand								
10.0				10.4-11.3 - Orange F-VF sand								
11.0				11.3-11.6 - Light tannish grey F-VF sand								
				11.6-12.0 Orange VF clayey silt								
12.0	12.0	14.0	#4	12.0-13.5 Orange VF sandy silt with grey clay stringers		95%	12' well casing		Moderate			Note well casing depth at 12.7'
13.0				13.5-13.9 - Saturated VF grey sand								
14.0	14.0	16.0	#5	14.0-14.6 - Saturated dark brownish black VF sandy silt		80%			Moderate			
15.0				14.6-15.6 - Moist brownish grey VF sand								
16.0												

BORING TERMINATED AT 18.0 FT BLS. LOGGED BY: C. Keith

COMMENTS:

FIELD LITHOLOGIC LOG

☐ EXCAVATION 120' East of CW-7A and			
SITE NAME AND LOCATION 60' N of CW-7A WT CAF Assessment - SE of WT Bldgs	**PROJECT NO.** 6498-019		**BORING / EXCAVATION NO.** WTB-15
DRILLING CONTRACTOR Skipper Well Drilling	**DRILLING METHOD** Push Drive Probe CIRCA Geoprobe		**SHEET** 3 OF 3
DRILLER R. Skipper	**SAMPLING METHOD** Hammered Core	**DRILLING** START TIME 12:45	**DRILLING** FINISH TIME 13:28
DRILLER P. Skipper			
GEOLOGIST C. Keith / J. Green - RTI	**WEATHER** Hot - 90's - Humid - SW 5-10	**DATE** 9-1-98	**DATE** 9-1-98
DRILL RIG Concord 9200	**SURFACE CONDITIONS** improved grassed grade.		
ANGLE Vert	**BEARING** —		
DATUM Land Surface	**ELEVATION** —	**COORDINATES** —	

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
16.0	16.0 to 18.0		#6	16.0 - 16.7 - Med Brown VF Sand	· · ·	80%			Difficult to Easy			
17.0				16.7 - 17.1 - Med Gray VF Sand	· · ·							
				17.1 - 17.6 - Gray stiff clay	– –							
18.0												

BORING TERMINATED AT 18.0 FT BLS. LOGGED BY: C. Keith

COMMENTS:

☐ EXCAVATION

FIELD LITHOLOGIC LOG

SITE NAME AND LOCATION on curve to East Bridge WT CAF Assessment – on WT East Access Rd	PROJECT NO. 6448-019	BORING / EXCAVATION NO. WTB-15
DRILLING CONTRACTOR Skipper Well Drilling	DRILLING METHOD Push Drive Probe circa Geoprobe	SHEET 1 OF 2
DRILLER R. Skipper	SAMPLING METHOD Hammered Core	DRILLING START TIME 08.08 / FINISH TIME 08:40
DRILLER P. Skipper		
GEOLOGIST C. Keith / RTI / J. Green	WEATHER Hot - 80's - Humid - SW 5-10	DATE 9-1-98 / DATE 9-1-98
DRILL RIG Concord 9200	SURFACE CONDITIONS Improved grassed grade	
ANGLE Vert.	BEARING —	
DATUM Land Surface	ELEVATION —	COORDINATES —

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
0.0	0.0	4.0	#1	0.0 – 0.6 – DARK BROWN ORGANIC VF to silty sand – ORGANIC material		100%			moderate			Note: strong methane odor from 2.0' BLS to 14.0' BLS
1.0				0.6 – 1.4 – Mottled stiff gray clay & orange oxidized VF sand								
				1.4 – 2.0 – Mottled Brown & orange clayey VF sand								
2.0 3.0				2.0 – 3.4 – Brownish Black sandy clayey silt with wood fragments – strong methane odor								
				3.4 – 4.0 – Gray & Brown sandy clay								
4.0	4.0	8.0	#2	4.0 – 4.5 – Gray & Brown sandy clay		100%	Well Casing Continued to 8.3' BLS		moderate	↑	7.39 BLS - 9.2.98 9.0 BLS - 9:25 - 9.1.98	
5.0				4.5 – 5.4 – Dark Brown & Gray clayey sand with wood fragments								
				5.4 – 6.0 – Salt & pepper VF sand								
6.0				6.0 – 6.4 – grayish tan slightly moist VF sand – gradational to								
7.0				6.4 – 7.1 – Dark Brown moist very silty VF sand								
8.0				7.1 – 8.0 – Moist dark Brown VF sand								

BORING TERMINATED AT 14.0 FT BLS.　　LOGGED BY: C. Keith / RTI

COMMENTS:

☑ BORING
☐ EXCAVATION

FIELD LITHOLOGIC LOG

SITE NAME AND LOCATION on curve to foot Bridge WT CaF Assessment - on WT East Access Rd	PROJECT NO. 6448-019	BORING / EXCAVATION NO. WTB-16
DRILLING CONTRACTOR Skipper Well Drilling	DRILLING METHOD Push Drive Probe Circa Geoprobe	SHEET 2 OF 2
DRILLER R. Skipper	SAMPLING METHOD Hammered Core	DRILLING START TIME 09:08 / FINISH TIME 09:40
DRILLER P. Skipper		
GEOLOGIST C. Keith / RTI / J. Greed	WEATHER Hot - 80's - Humid	START DATE 9-1-98 / FINISH DATE 9-1-98
DRILL RIG Concord 9200	SURFACE CONDITIONS improved grassed grade.	
ANGLE Vert. / BEARING —		
DATUM Land Surface / ELEVATION —	COORDINATES —	

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
8.0	8.0	~~10.0~~ 12.0	#3	8.0-9.4- Saturated dark Brown silty VF Sand					Moderate to Difficult			Void casing Depth At left
9.0				9.4-10.0 - Saturated med Brown silty VF Sand		100%						
10.0				10.0- 10.5- Brownish tan F-VF Sand								
				10.5- 10.9- Light tan F-Med Sand								
11.0				10.9-11.1 med tan F-VF Sand with gray clay nodules								
				11.1-11.2 Grayish Green silty clay								
				11.2-12.0 Light Gray silty sandy clay								
12.0	12.0	14.0	#4	12.0-14.0 - Saturated sandy silty gray Loose clay		100%			Difficult			
13.0												
14.0												

BORING TERMINATED AT 14.0 FT BLS. LOGGED BY: C. Keith / RTI

COMMENTS:

☑ BORING
☐ EXCAVATION

FIELD LITHOLOGIC LOG

SITE NAME AND LOCATION WT CaF Assessment - SE of WT Bldg's	PROJECT NO. 6948-019	BORING / EXCAVATION NO. WTB-17
DRILLING CONTRACTOR Skipper Well Drilling	DRILLING METHOD Push Drive Probe Circa Geoprobe	SHEET 1 OF 2
DRILLER R. Skipper	SAMPLING METHOD Hammered Core	DRILLING START TIME 10:35 / FINISH TIME 10:52
DRILLER P. Skipper		
GEOLOGIST C. Keith / RTI / J. Green	WEATHER Hot - 80's-90's - Humid - SW-5-10	START DATE 9-1-98 / FINISH DATE 9-1-98
DRILL RIG Concord 9200	SURFACE CONDITIONS Improved grassed grade	
ANGLE Vert. / BEARING —		
DATUM Land Surface / ELEVATION —	COORDINATES —	

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
0.0	0.0	4.0	#1	0.0 - 4.0 - DARK Brownish Sandy silt - highly organic with mottled orange: grey stringers - wet at bottom		100%			Easy		4.0 - 10:38 - 9-1-98 3.11 - 9-2-98	
1.0												
2.0												
3.0												
4.0	4.0	8.0	#2	4.0 - 6.0 DARK greyish Black VF to silty Sand Saturated - organics		80%	WELL CASING & continued to 8.05' BLS		Moderate			
5.0												
6.0				6.0-6.2 Brown VF Sandy clay								
				6.2-6.6 Saturated Med-F greyish tan Sand								
				6.6-6.9 - Greyish tan VF Sand								
7.0				6.9-7.2 - Greyish tan VF sandy clay								
8.0												

BORING TERMINATED AT 14.0 FT BLS. LOGGED BY: C. Keith / RTI

COMMENTS:

☐ EXCAVATION

FIELD LITHOLOGIC LOG

SITE NAME AND LOCATION WT CAF Assessment - SE of WT Bldgs	PROJECT NO. 6448-019	BORING / EXCAVATION NO. WTB-17
DRILLING CONTRACTOR Skipper Well Drilling	DRILLING METHOD Push Drive Probe CIRCA Geoprobe	SHEET 2 OF 2
DRILLER R. Skipper	SAMPLING METHOD Hammered Core	DRILLING START TIME 10:35 / FINISH TIME 10:52
DRILLER P. Skipper		
GEOLOGIST C. Keith / J. Green - RTI	WEATHER Hot - 80's - 90's - Humid - SW 5-10	START DATE 9-1-98 / FINISH DATE 9-1-98
DRILL RIG Concord 9200	SURFACE CONDITIONS improved grassed grade.	
ANGLE Vert. / BEARING —		
DATUM Land Surface / ELEVATION —	COORDINATES	

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
8.0				8.0 - 8.9 - Moist Gray med - F Sand								
9.0	8.0	12.0	#3	8.9 - 10.5 - Saturated greyish tan clayey silt		100%	Void Well Casing		moderate			Void well casing depth to left
10.0												
11.0				10.5 - 12.0 - Moist greyish Brown clayey silty . . . VF Sand								
12.0				12.0 - 12.5 - Moist Brown med to VF Sand								
13.0	12.0	14.0	#4	12.5 - 14.0 - Mottled Light grey to Greenish stiff Clay + Grey VF sandy clay		100%			Easy			
14.0												

BORING TERMINATED AT 14.0 FT BLS. LOGGED BY: C. Keith

COMMENTS:

☑ BORING
☐ EXCAVATION

FIELD LITHOLOGIC LOG

SITE NAME AND LOCATION Centered Between Lagoons WT CaF Assessment - on E WT Ditch Bank	PROJECT NO. 6448-019	BORING / EXCAVATION NO. WTB-18
DRILLING CONTRACTOR Skipper Well Drilling	DRILLING METHOD Push Drive Probe CIRCA Geoprobe	SHEET 1 OF 2
DRILLER R. Skipper	SAMPLING METHOD Hammered Core	DRILLING START TIME 13:00 / FINISH TIME 13:25
DRILLER P. Skipper		
GEOLOGIST C. Keith/RTE	WEATHER Sunny - 90's - SW 3	START DATE 8-24-98 / FINISH DATE 8-24-98
DRILL RIG Concord 9200	SURFACE CONDITIONS improved grassed grade	
ANGLE Vert. / BEARING —		
DATUM Land Surface / ELEVATION —	COORDINATES —	

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
0.0	0.0	4.0	#1	0.0 to 0.7 - Light Brown Sand with organic material		68%			Easy			
1.0				0.7-1.4 med Brownish/grey VF Sand - som organic mtl.								
2.0				1.4-2.7 - dark Brown to Black VF to silty organic sand								
3.0				—								
4.0	4.0	8.0	#2	4.0 - 5.1 - Brown saturated F-VF Sand with wood particles		80%			Moderate to Difficult	^	13:05 - 8-24-98 - 4.0 BLS	
5.0				5.1 - 5.6 - Med Brown moist VF Sand								
6.0				5.6 - 6.6 - Moist Grey Clayey VF Sand								
7.0				6.6 - 7.2 - Brownish/Grey VF Sand with dark Brown organic stringer at 6.6								
8.0												

BORING TERMINATED AT 14.0 FT BLS. LOGGED BY: C. Keith/RTE

COMMENTS:

☑ BORING
☐ EXCAVATION

FIELD LITHOLOGIC LOG

SITE NAME AND LOCATION: Centered Between Lagoons WT CAF Assessment - on East Ditch Bank
PROJECT NO.: 6448-019
BORING / EXCAVATION NO.: WTB-18
DRILLING CONTRACTOR: Skipper Well Drilling
DRILLING METHOD: Push Drive Probe GIRCA Geoprobe
SHEET: 2 OF 2
DRILLER: R. Skipper
SAMPLING METHOD: Hammered Core
DRILLER: P. Skipper

DRILLING	START	FINISH
TIME	13:00	13:25
DATE	8-29-98	8-29-98

GEOLOGIST: C. Keith / RTI
WEATHER: Sunny - 90's - SW 3
DRILL RIG: Concord 9200
SURFACE CONDITIONS: improved grassed grade.
ANGLE: Vert.
BEARING: —
DATUM: Land Surface
ELEVATION: —
COORDINATES: —

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
8.0				Above 8.0 – 8.05 Soupy Brown VF Sand with Silt								
9.0	8.0 to 10.0		#3			3%			Easy			
10.0				10.0–10.9 – Gray Clayey saturated Sand								
11.0	10.0 to 12.0		#4	10.9 – 11.8 – Gray Stiff Clay		95%			Easy to Difficult			
				11.6 – 11.9 – Light Gray saturated Clayey VF Sand								
12.0				12.0 – 12.5 – Light Gray very very Fine Sand								
13.0	12.0 to 14.0		#5	12.5 – 13.8 – Dark Brownish Black Stiff Clay		90%			Moderate			
14.0												

BORING TERMINATED AT 14.0 FT BLS.
LOGGED BY: C. Keith / RTI
COMMENTS:

☑ BORING
☐ EXCAVATION

FIELD LITHOLOGIC LOG

SITE NAME AND LOCATION SE woodline WT CAF Assessment - 55' East of WT	PROJECT NO. 6448-019	BORING / EXCAVATION NO. WTB-19
DRILLING CONTRACTOR Skipper Well Drilling	DRILLING METHOD Push Drive Probe Circa Geoprobe	SHEET 1 OF 2
DRILLER R. Skipper	SAMPLING METHOD Hammered Core	DRILLING START TIME 14:05 / FINISH TIME 14:25
DRILLER P. Skipper		
GEOLOGIST C. Keith / RTC	WEATHER Sunny - 90's - SW 3	START DATE 8-29-98 / FINISH DATE 8-29-98
DRILL RIG Concord 9200	SURFACE CONDITIONS improved road shoulder fill.	
ANGLE Vert.	BEARING —	
DATUM Land Surface	ELEVATION —	COORDINATES —

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
0.0	0.0	4.0	#1	0.0 - 0.6 - tan/Brown to Black VF Sand with organic mtl.		85%			Easy			
1.0				0.6 - 3.4 - Dark Brownish Black VF Silty Sand grades to saturated at 3.0' BLS								
2.0												
3.0										3.0		
4.0	4.0	8.0	#2	4.0 - 5.0 - Saturated Dark Brown VF to silty sand		95%	G.GP Well Casing		Moderate		3.0' BLS - 14:10 - 9-	
5.0				5.0 - 5.8 - Tan Clayey VF Sand								
6.0				5.8 - 7.8 - Greenish/tannish gray clayey sand with wood particles								
7.0												
8.0												

BORING TERMINATED AT 12.0 FT BLS. LOGGED BY: C. Keith / RTC

COMMENTS:

☑ BORING
☐ EXCAVATION

FIELD LITHOLOGIC LOG

SITE NAME AND LOCATION WT CAF Assessment - 55' East of WT SE Woodline	PROJECT NO. 6498-019	BORING / EXCAVATION NO. WTB-19
DRILLING CONTRACTOR Skipper Well Drilling	DRILLING METHOD Push Drive Probe Circa Geoprobe	SHEET 2 OF 2
DRILLER R. Skipper	SAMPLING METHOD Hammered Core	DRILLING START TIME 14:05 / FINISH TIME 14:25
DRILLER P. Skipper		
GEOLOGIST C. Keith / RTI	WEATHER Sunny - 90's - SW 3	START DATE 8-29-98 / FINISH DATE 8-29-98
DRILL RIG Concord 9200	SURFACE CONDITIONS improved Road shoulder Fill.	
ANGLE Vert.	BEARING —	
DATUM Land Surface	ELEVATION —	COORDINATES —

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
8.0	8.0	10.0	#3	8.0- 8.4- DARK Brown Clayey Sand		100%			Moderate			
9.0				8.4-9.5'- Light : DARK grey Clay : Sand with dark grey moderately stiff clay stringers								
				9.5-10.0- Light tan slightly clayey VF Sand								
10.0	10.0	12.0	#4	10.0-12.0- Light tannish grey med. to VF saturated saturated to moist Sand feldspar grains		100%			Difficult			
11.0												
12.0												

BORING TERMINATED AT 12.0 FT BLS.   LOGGED BY: C. Keith / RTI

COMMENTS:

FIELD LITHOLOGIC LOG

☐ EXCAVATION

SITE NAME AND LOCATION WT CoF Assessment - due East of WT Bldgs	**PROJECT NO.** 6498-019	**BORING / EXCAVATION NO.** WTB-20
DRILLING CONTRACTOR Skipper Well Drilling	**DRILLING METHOD** Push Drive Probe Circa Geoprobe	**SHEET** 1 OF 2
DRILLER R. Skipper	**SAMPLING METHOD** Hammered Core	**DRILLING** START TIME 09:13 / FINISH TIME 09:32
DRILLER P. Skipper		
GEOLOGIST C. Keith/T. Green - ETI	**WEATHER** Hot - 80's-90's - Humid - SW 5-10	START DATE 9-2-98 / FINISH DATE 9-2-98
DRILL RIG Concord 9200	**SURFACE CONDITIONS** improved grassed grade	
ANGLE Vert. / **BEARING** —		
DATUM Land Surface / **ELEVATION** —	**COORDINATES** —	

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
0.0	0.0	4.0	#1	0.0-0.3 DARK Brown VF Silty Sand with organic material		100%			Easy			
1.0				0.3-2.1 - mottled tan/orange & DARK Brown VF Silty Sand								
2.0				2.1-4.0 - DARK Brown organic VF Silty Sand with light gray VF Sand stringers saturated								
3.0												
4.0	4.0	8.0		4.0-4.2 - dark Brown sandy Silt 4.2-4.8 - tan Brown F-VF Sand 4.8-5.4 - Saturated DARK Brown VF Silty Sand		85%	8.0 - Well Casing		Moderate		7.30 - 9-2-98 - TOC 4.0 - 09:18 - 9-2-98 - BLS	
5.0				5.4-5.8 - DARK Gray compacted organic Silt 5.8-6.1 - Highly organic Silt: pepper VF sand with wood fragments								
6.0				6.1-6.5 - light Gray F-VF Sand 6.5-7.4 - moist to saturated Highly organic DARK Blackish/Brown Sandy Silt								
7.0												
8.0												

BORING TERMINATED AT 19.0 FT BLS. LOGGED BY: C. Keith

COMMENTS:

☐ EXCAVATION

FIELD LITHOLOGIC LOG

SITE NAME AND LOCATION WTB CAF Assessment - due East of WT Bldgs	PROJECT NO. 6448-019	BORING / EXCAVATION NO. WTB-20
DRILLING CONTRACTOR Skipper Well Drilling	DRILLING METHOD Push Drive Probe Circa Geoprobe	SHEET 2 OF 2
DRILLER R. Skipper	SAMPLING METHOD Hammered Core	DRILLING START TIME 09:13 / FINISH TIME 09:32
DRILLER P. Skipper		
GEOLOGIST C. Keith / J. Green - RTI	WEATHER Hot - 80's - 90's - Humid - SW-5-10	START DATE 9-2-98 / FINISH DATE 9-2-98
DRILL RIG Concord 9200	SURFACE CONDITIONS improved grassed grade	
ANGLE Vert.	BEARING —	
DATUM Land Surface	ELEVATION —	COORDINATES —

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
8.0				8.0-10.0 - Saturated dark Brown VF silty sand with organic material								
9.0	8.0	12.0	#3									
10.0				10.0-10.8 - Moist DARK Brown to light tannish grey VF silty sand		100%			Moderate			
				10.8-11.4 - Moist light Grey clayey silty sand								
11.0				11.4-12.0 - Saturated F-VF light Grey sand								
12.0				12.0-12.2 Saturated light Grey F-VF Sand								
				12.2-13.2 - Mottled orange & light grey slightly sandy clay								
13.0	12.0	14.0	#4			60%			Moderate			
14.0												

BORING TERMINATED AT 14.0 FT BLS. LOGGED BY: C. Keith

COMMENTS:

FIELD LITHOLOGIC LOG

☐ EXCAVATION

SITE NAME AND LOCATION of Woodsedge on CR-1 Rd WTB-21- WTCAF Assessment - 195' EAST	**PROJECT NO.** 6448-019	**BORING / EXCAVATION NO.** WTB-21
DRILLING CONTRACTOR Skipper Well Drilling	**DRILLING METHOD** Push Drive Probe Circa Geoprobe	**SHEET** 1 OF 2
DRILLER R. Skipper	**SAMPLING METHOD** Hammered Core	**DRILLING** START TIME 10:35 / FINISH TIME 1507
DRILLER P. Skipper		
GEOLOGIST C. Keith / J. Green	**WEATHER** Hot-Sunny-Humid-90s-SE5	START DATE 8-29-98 / FINISH DATE 8-29-98
DRILL RIG Concord 9200	**SURFACE CONDITIONS** improved grassed road shoulder	
ANGLE Vert / **BEARING** —		
DATUM Land Surface / **ELEVATION** —	**COORDINATES** —	

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
0.0	0.0 to	4.0	#1	0.0-1.2 - Light tan VF Sand with organic material - Roadfill		50%			Easy			
1.0				1.2-2.0 - Black VF to silty organic sand - moist at Bottom								
2.0												
3.0												
4.0	4.0 to	8.0	#2	4.0-5.3 - Black VF to mostly silty organic saturated Sand		88%			Moderate	↑	4.0' BLS - 10:40 - 8-29-98	
5.0				5.3-6.4 - Moist grey slightly Clayey Sand								
6.0				6.4-7.5 - Moist Brown Fine to VF Sand with wood fragments			7.65' Well Casing					
7.0												
8.0												

BORING TERMINATED AT 14.0 **FT BLS.** **LOGGED BY:** C. Keith

COMMENTS:

☐ EXCAVATION

FIELD LITHOLOGIC LOG

SITE NAME AND LOCATION Edge on CW-1 Rd WTC&F Assessment - 195' East of woods	**PROJECT NO.** 6498-019	**BORING / EXCAVATION NO.** WTB-21
DRILLING CONTRACTOR Skipper Well Drilling	**DRILLING METHOD** Push Drive Probe Circa Geoprobe	**SHEET** 2 OF 2
DRILLER R. Skipper	**SAMPLING METHOD** Hammered Core	**DRILLING** START TIME 10:35 / FINISH TIME 11:07
DRILLER P. Skipper		
GEOLOGIST C. Keith / J. Green	**WEATHER** Hot-sunny-Humid-90's-SES	START DATE 8-24-98 / FINISH DATE 8-24-98
DRILL RIG Concord 9200	**SURFACE CONDITIONS** improved grassed road shoulder	
ANGLE Vert. / **BEARING** —		
DATUM Land Surface / **ELEVATION** —	**COORDINATES** —	

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
8.0	8.0 to 10.0		#3	8.0 - 8.3 - Med Brown moist F-VF Sand		60%			Difficult to Easy			
				8.3 - 8.7 - Brownish Black VF to Silty organic Sand								
9.0				8.7 - 9.2 - Saturated Dark gray Silty Sand with wood mtl								
10.0	10.0 to 12.0		#4	10.0 - 10.8 Gray saturated Silty VF Sand		95%			Difficult			
11.0				10.8 - 11.3 - Greenish Gray Dense Clay								
				11.3 - 11.9 Light gray moist VF Sand								
12.0	12.0 to 14.0		#5	12.0 - 13.2 - Very Light gray Extremely fine Sand Saturated		95%			moderately Difficult to Easy			
13.0				13.2 - 13.9 - Dark Brownish Black Dense Clay								
14.0												

BORING TERMINATED AT 14.0 FT BLS.   LOGGED BY: C. Keith

COMMENTS:

☐ EXCAVATION

FIELD LITHOLOGIC LOG

SITE NAME AND LOCATION WT CAF Assessment - Beside CW-6A	PROJECT NO. 6448-019	BORING / EXCAVATION NO. WTB-22
DRILLING CONTRACTOR Skipper Well Drilling	DRILLING METHOD Push Drive Probe Circa Geoprobe	SHEET 1 OF 2
DRILLER R. Skipper	SAMPLING METHOD Hammered Core	DRILLING START TIME 09:05 / FINISH TIME 09:25
DRILLER P. Skipper		
GEOLOGIST C. Keith /RTI / Jason Green	WEATHER Sunny - 90's - SW 5	START DATE 8-24-98 / FINISH DATE 8-24-98
DRILL RIG Concord 9200	SURFACE CONDITIONS improved grassed grade.	
ANGLE Vert. / BEARING —		
DATUM Land Surface / ELEVATION —	COORDINATES —	

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
0.0	0.0	4.0	#1	0.0-0.4 - Light Brown Fine Sand		100%			Easy			
1.0				0.4-2.0 - Black moist very Fine to silty SAND - ORGANIC MATERIAL								
2.0 3.0				2.0-4.0 - Dark Gray Clayey SAND - moist with root & few material								
4.0	4.0	8.0	#2	4.0-4.9 Light Gray moist Clayey Silty Sand		85%	6.0' well casing		Difficult		5.4 - 8-24-98 - 09:10	
5.0				4.9-5.4 - Light Gray moist Fine Sand								
6.0 7.0				5.4-7.4 - Saturated Light Gray Fine Sand								
8.0												

BORING TERMINATED AT 12.0 FT BLS.

LOGGED BY: C. Keith /RTI

COMMENTS:

☑ BORING
☐ EXCAVATION

FIELD LITHOLOGIC LOG

SITE NAME AND LOCATION N of WT AREA WTCAF Assessment - Beside CW-6A	PROJECT NO. 6448-019	BORING / EXCAVATION NO. WTB-22
DRILLING CONTRACTOR Skipper Well Drilling	DRILLING METHOD Push Drive Probe Circa Geoprobe	SHEET 2 OF 2
DRILLER R. Skipper	SAMPLING METHOD Hammered Core	DRILLING START TIME / FINISH TIME
DRILLER P. Skipper		
GEOLOGIST C. Keith / RTI	WEATHER Sunny - 90's - SW 5	DATE 8-24-98 / DATE 8-24-98
DRILL RIG Concord 9200	SURFACE CONDITIONS improved grassed grade.	
ANGLE Vert. / BEARING —		
DATUM Land Surface / ELEVATION —	COORDINATES —	

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
8.0	8.0	10.0	#3	8.0 - 9.1 - Dark Brown moist to saturated Clayey sand		35%			Difficult			
9.0												
10.0	10.0	12.0	#4	10.0 - 10.7 Light Bluish Gray very fine Sandy saturated Clay		95%			Difficult			
11.0				10.7 - 11.5 Light Bluish Gray very Silty clay								
				11.5 - 11.9 - Bluish Gray Dense Clay								
12.0												

BORING TERMINATED AT 12.0 FT BLS.   LOGGED BY: C. Keith / RTI

COMMENTS:

☑ BORING
☐ EXCAVATION

FIELD LITHOLOGIC LOG

SITE NAME AND LOCATION WT CAF Assessment - 500' E of WTB-8 on CW-6 Road	PROJECT NO. 6948-019	BORING / EXCAVATION NO. WTB-23
DRILLING CONTRACTOR Skipper Well Drilling	DRILLING METHOD Push Drive Probe Circa Geoprobe	SHEET 1 OF 2
DRILLER R. Skipper	SAMPLING METHOD Hammered Core	DRILLING START TIME 14:04 / FINISH TIME 14:55
DRILLER R. Malpass		
GEOLOGIST C. Keith / RTI	WEATHER 80's - NE5 - sunny	START DATE 8-20-98 / FINISH DATE 8-20-98
DRILL RIG Concord 9200	SURFACE CONDITIONS improved Roadgrade	
ANGLE Vert. / BEARING —		
DATUM Land Surface / ELEVATION —	COORDINATES —	

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
0.0	0.0	4.0	#1	0.0-2.0 - dk Black organic sandy silt		100%	Well casing		Hard			
2.0				2.0-4.0 - med. Brown VF clayey sand								
4.0	4.0	8.0	#2	4.0-4.5 Black organic silt & Brown VF Sand		87%			Hard			
4.5				4.5-5.5 - Light grey moist clayey sand with oxidation pockets								
5.5				5.5-6.9 - Light greyish/tan moist VF sand							6.9' BLS 14:36 8/20/98 6.01 8-21-98	
6.9				6.9-7.5 dk Brownish/Black saturated clayey silty sand								
8.0												

BORING TERMINATED AT 12.0 FT BLS. LOGGED BY: C. Keith

COMMENTS:

☑ BORING
☐ EXCAVATION

FIELD LITHOLOGIC LOG

SITE NAME AND LOCATION on CW-6 Road WT CAF Assessment - 500' E of WTB-8	PROJECT NO. 6448-019	BORING / EXCAVATION NO. WTB-23
DRILLING CONTRACTOR Skipper Well Drilling	DRILLING METHOD Push Drive Probe Circa Geoprobe	SHEET 2 OF 2
DRILLER R. Skipper	SAMPLING METHOD Hammered Core	DRILLING START / FINISH
DRILLER R. Malpass		TIME 14:04 / 14:55
GEOLOGIST C. Keith / RTI	WEATHER 80's – NE 5 – Sunny	DATE 8-20-98 / 8-20-98
DRILL RIG Concord 9200	SURFACE CONDITIONS improved road grade	
ANGLE Vert.	BEARING —	
DATUM Land Surface	ELEVATION —	COORDINATES —

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
8.0	8.0	10.0	#3	8.0 – 8.2 grey saturated clayey VF sand		10%			Easy			
9.0												
10.0	10.0	12.0	#4	10.0 – 12.0 grey stiff sandy clay with large wood particle	~	100%			Easy			
11.0												
12.0												
13.0												
14.0												

BORING TERMINATED AT 12.0 FT BLS.   LOGGED BY: C. Keith

COMMENTS:

WT Area Investigation Lithologic Logs

Borings/Monitoring Wells

Logging Performed by Research Triangle Institute

Boring Number	Well Number
WT-18A	WT-18A
WT-19A	WT-19A
WTB-24	none
WTB-25	WT-10A
WTB-26	WT-7, -7B, -7C
WTB-27	WT-11A
WTB-28	WT-12A
WTB-29	WT-13A, -13B
WTB-30	WT-14A, -14B
WTB-31	none
WTB-32	none
WTB-33	WT-7, -7B, -7C
WTB-34	Ditch Well
WTB-35	none
WTB-36	WT-15B
WTB-37	WT-16B
WTB-38	WT-17B

* see Figure 1-2 for boring/well location

☐ EXCAVATION

SITE NAME AND LOCATION GE-WILMINGTON	PROJECT NO. 6448-020	BORING / EXCAVATION NO. WT-18A
DRILLING CONTRACTOR SKIPPERS	DRILLING METHOD DIRECT PUSH	SHEET 1 OF 3
DRILLER R. SKIPPER	SAMPLING METHOD DIRECT PUSH / ACETATE SLEEVES	DRILLING START TIME 930a FINISH TIME 11:30a
DRILLER S. PARRISH		
GEOLOGIST J. REYNOLDS	WEATHER CLEARING, WARM 70's	START DATE 12/14/99 FINISH DATE 12/14/99
DRILL RIG	SURFACE CONDITIONS GRASSED & LEVEL, INSIDE WT AREA	
ANGLE 0 BEARING —		
DATUM LAND SURFACE ELEVATION	COORDINATES	

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
0				0'-0.2' LT BROWN TO BROWN ORGANIC SILTY SAND W/ ABUNDANT ROOT MASS								
1				0.2'-4' VERY DUSKY RED TO DARK BROWN SILTY VF TO FINE SAND (MOIST @ APPROX. 1.5') (SM)								4' SAMPLING TUBE-COMPRESSED SAMPLE - 3.6' OF SAMPLE RECOVERED
2												
3												
4				4'-7.1' VARIEGATED GRAY TO PREDOMINATELY GRAYISH BROWN SILTY FINE SAND. (SM)								0ppm NO_3 @ ~7.0' (STRIP IN 50:50 SOIL : H_2O SLURRY)
5												4' SAMPLING TUBE COMPRESSED SAMPLE - 2.7' OF SAMPLE RECOVERED
6				7.1~7.2 GRAY & BLACK PLASTIC FIN. SANDY CLAY W/ THIN YELLOW STRINGERS (CL)								
7				7.2-7.3 GRAY, FINE-MED QUARTZ SAND (POORLY GRADED) (SP) 7.3-8.0 DARK REDDISH BROWN FINE-MED SAND (SP)								GRAY ZONES IN 4.0-7.1' SEGMENT PRIMARILY CLAYEY SAND
8												

BORING TERMINATED AT 20 FT BLS.

LOGGED BY: Jeff Reynolds

COMMENTS:

☐ EXCAVATION

SITE NAME AND LOCATION GE-WILMINGTON	PROJECT NO. 6448-020	BORING / EXCAVATION NO. WT-18A
DRILLING CONTRACTOR SKIPPERS	DRILLING METHOD DIRECT PUSH	SHEET 2 OF 3
DRILLER R. SKIPPER	SAMPLING METHOD DIRECT PUSH	DRILLING START TIME 930a / FINISH TIME 1130a
DRILLER S. PARRISH		
GEOLOGIST J. REYNOLDS	WEATHER CLEARING WARM 70s	START DATE 12/14/99 / FINISH DATE 12/14/99
DRILL RIG	SURFACE CONDITIONS GRASSED/FLAT	
ANGLE 0 DEV / BEARING —		
DATUM LAND SURF. / ELEVATION —	COORDINATES	

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
8 9 10 11				DARK REDDISH-BROWN FINE-MEDIUM SAND (TOP 0.3') GRADING TO A YELLOWISH BROWN, FINE-MEDIUM CLEAN QUARTZ SAND TO 10.0' (MOIST) (SW) DARK GRAY TO BLACK, VERY SILTY VF-FINE SAND 10.0-11.0 (MOIST) (SM) GRAY STIFF TO VERY STIFF SL. SANDY CLAY (CL)								0ppm NITRATE @ ~9.0' 4' SAMPLING TUBE. COMPRESSED/RECOVERED SAMPLE LENGTH = 3.0'
12 13				GRAY STIFF TO VERY STIFF SL. SANDY CLAY (CL)		100%						
14 15 16				GRAY STIFF TO VERY STIFF SL. SANDY CLAY (CL)		100%						

SCREEN, WT-18A (EXPECTED)

BORING TERMINATED AT 20 FT BLS. LOGGED BY: JWReynolds

COMMENTS:

☐ EXCAVATION

SITE NAME AND LOCATION GE-WILMINGTON	**PROJECT NO.** 6448-020	**BORING / EXCAVATION NO.** WT-18A
DRILLING CONTRACTOR SKIPPERS	**DRILLING METHOD** DIRECT PUSH	**SHEET** 3 OF 3
DRILLER R. SKIPPER	**SAMPLING METHOD** DIRECT PUSH	**DRILLING** START TIME 930a / FINISH TIME 1130a
DRILLER S. PARRISH		
GEOLOGIST J. REYNOLDS	**WEATHER** CLEARING / WARM 70's	START DATE 12/14/99 / FINISH DATE 12/14/99
DRILL RIG	**SURFACE CONDITIONS** GRASSED / FLAT	
ANGLE 0 DEV	**BEARING** —	
DATUM LAND SURFACE	**ELEVATION**	**COORDINATES**

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
16				LIGHT GRAY V.FINE SANDY SILT (WET) (~~ML~~)ML SM 16.0-17.4								
17				17.4'-18' GREENISH GRAY SILTY TO ~~[illegible]~~ SANDY SOFT CLAY		100%	NA ↓	NM ↓	NM ↓			
18				18.0-19.8 GRAY TO GREENISH GRAY F. SANDY CLAY								
19				19.8-~~20~~ GREENISH GRAY VERY SILTY SAND (SM)		100%						
20												

BORING TERMINATED AT 20 FT BLS.

LOGGED BY:

COMMENTS:

☐ EXCAVATION

SITE NAME AND LOCATION GE- WILMINGTON	PROJECT NO. 6448-020	BORING / EXCAVATION NO. WT- 19A
DRILLING CONTRACTOR SKIPPERS	DRILLING METHOD H.S. AUGER	SHEET 1 OF 2
DRILLER R. SKIPPER	SAMPLING METHOD SPLIT SPOON	DRILLING START TIME ~10a / FINISH TIME ~2:00p
DRILLER S. PARRISH		
GEOLOGIST J. REYNOLDS	WEATHER OVERCAST → HEAVY RAIN. LOW. 70s	START DATE 12/13/99 / FINISH DATE 12/13/99
DRILL RIG	SURFACE CONDITIONS GRASSED/FLAT. INSIDE FENCED AREA, NT	
ANGLE 0 DEG / BEARING —		
DATUM LAND SURFACE / ELEVATION	COORDINATES	

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
0 1	0 TO 1.5			V. DARK BROWN TO BROWNISH BLACK, HIGHLY ORGANIC, V. SILTY FINE SAND (DRY). SOME GRASS/ROOTS IN UPPER 0.5' (SM)		75% (2.5')	NA ↓	NM ↓	NM ↓			
				NR								NR= NO RECOVERY
2 3	2.0 TO 3.4			2.0-2.5-V. DARK BROWN HIGHLY ORGANIC V. SILTY FINE SAND BECOMING MOIST @ ~2.5' (SM) 2.5-2.8-CLAYEY DARK BROWN F SAND (SC) 2.8-3.5-BROWNISH GRAY, MOIST SILTY FINE-MED SAND (SM) 3.5-3.8-SL. CLAYEY, SILTY FINE-MED SAND (BROWNISH-GRAY & MOIST) (SC)		90%						
				NR								NR
4 5	4.0 TO 6.0			4.0-4.3 D. GRAYISH BROWN SILTY (MOIST) FINE SAND (SM) 4.3-5.2 GRAY, WET CLAYEY FINE SAND (SC) 5.2-5.8 GRAY MOIST V. SILTY TO CLAYEY FINE-MED SAND (SC) 5.8-6.0 DRY (COMPACTED) DARK GRAYISH BROWN SL. CLAYEY SAND (SC)		100%						
6 7	6.0 TO 7.5			6.0-7.0. DK. GRAYISH BROWN DRY, V. SILTY FINE SAND (SM) 7.0-7.5-DK. GRAY MOIST SL. SILTY FINE-MED SAND (SM)		75%						
8				NR								NR

BORING TERMINATED AT 16 FT BLS. LOGGED BY: J. Reynolds

COMMENTS: SAMPLES RETAINED IN CORE BOX

☐ EXCAVATION

SITE NAME AND LOCATION GE-Wilmington	PROJECT NO. 6448-020	BORING / EXCAVATION NO. WT-19A
DRILLING CONTRACTOR Skipper's	DRILLING METHOD H.S. Auger	SHEET 2 of 2
DRILLER R. Skipper	SAMPLING METHOD Split Spoon	DRILLING START: TIME ~10a, DATE 12/13/99 FINISH: TIME ~2p, DATE 12/13/99
DRILLER S. Parrish		
GEOLOGIST J. Reynolds	WEATHER Overcast → Heavy Rain low 70s	
DRILL RIG	SURFACE CONDITIONS Grassed / Flat inside fenced area, W.T.	
ANGLE 0 deg.	BEARING –	
DATUM Land Elev.	ELEVATION	COORDINATES

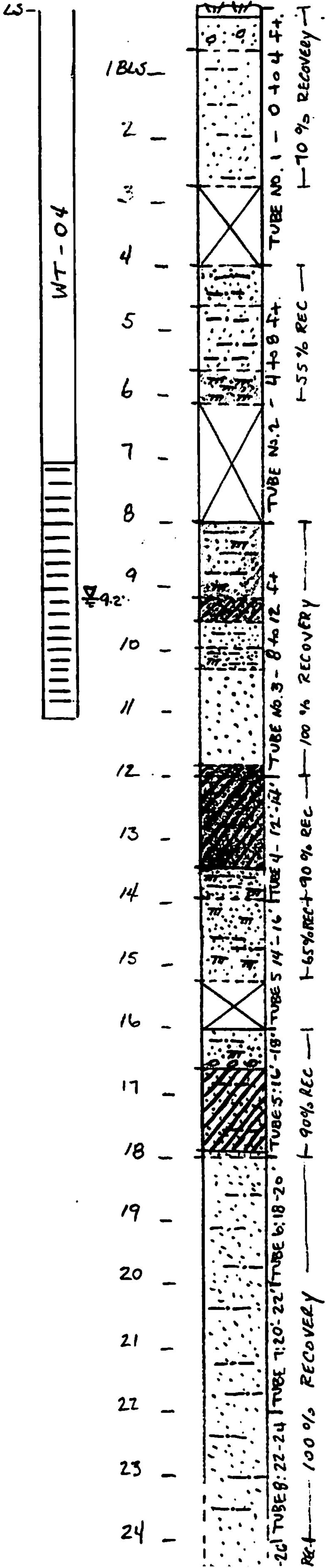
DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
8 9				(0.5' recovery, uncertain location) Gray, very plastic, sl f. sandy clay (CL)		~25%	NA	NM	NM			Uncertain location
10 11	10.0	12.0		10.0-11.2 Dark gray, very fine sandy clay, grading to gray, clayey, fine sand (SC) 11.2-12.0 · Light gray, silty dry ~~very~~ f. sand (SM)		100%						
12 13	12.0	13.2		12.0-12.5 - Dark gray, wet clayey fine sand (SC) 12.5-13.3 wet, gray, sl. silty very fine sand (SM)								
				13.3 NR								NR
14 15 16	14.0	16.0		14.0-14.2 - wet clayey dark gray fine to med. sand (SC) 14.2-14.8 - Lt. greenish gray (CL) vf to v. coarse qtz sandy clay 14.8-15.9 - Lt. greenish gray vf to coarse sandy clay w/ wood fragments (CL) 15.9-16.0 Lt. pale green very f. to fine sand (SW)		100%						

BORING TERMINATED AT 16 FT BLS. LOGGED BY: J. Reynolds

COMMENTS:

RTIL [redacted]

PROJECT WT ASSESSMENT JOB NO. 8473-014 DATE [illegible]
COMPUTED BY Scott CHECKED BY ______ DATE CHECKED ______
WTB - 24
ASSESSMENT AREA 1
CLIENT GE-WILMINGTON PAGE NO. 1 OF 1



SOIL

BROWN, FINE TO MEDIUM SAND W/ FINE TO MEDIUM GRAVEL (FILL).

MOTTLED BROWN TO BLACK SILTY MEDIUM TO FINE SAND.

NO SAMPLE.

BLACK VERY SILTY MEDIUM TO FINE SAND.

BROWN TO BLACK VERY SILTY MEDIUM TO FINE SAND.

BLACK, VERY SILTY, SLIGHTLY CLAYEY MEDIUM TO FINE DENSE SAND.

NO SAMPLE

BLACK TO BROWN, VERY SILTY, SLIGHTLY CLAYEY FINE TO MEDIUM SAND (SATURATED). NO_3 >10 <50 ppm

MINOR, BLACK TO GRAY, VERY SANDY CLAY.

BROWN, SLIGHTLY SILTY, FINE TO MEDIUM SAND. NO_3 < 10 ppm

BROWN AND BLACK, VERY SILTY, CLAYEY MEDIUM TO FINE DENSE SAND.

BROWN, SILTY, FINE TO MEDIUM SAND (SATURATED). NO_3 < 10 ppm

BLACK, SILTY, VERY CLAYEY FINE TO MEDIUM SAND (to) A SILTY VERY SANDY SOFT CLAY.

BLACK, VERY SILTY, VERY FINE to FINE SANDY CLAY WITH WOODY INCLUSIONS.

GRAY TO BLACK, VERY SILTY, VERY FINE TO FINE SAND W/ LENSES (0.01') OF FIRM YELLOW/BROWN CLAY. NO_3 > 10 ppm (?)

LIGHT GRAY, VERY SILTY, VERY FINE SAND W/ CLAYEY ZONES.

NO SAMPLE

(SAME) LIGHT GRAY, VERY SILTY, VERY FINE SAND W/ CLAYEY ZONES AND COARSE GRAVEL AT BASE (2%)

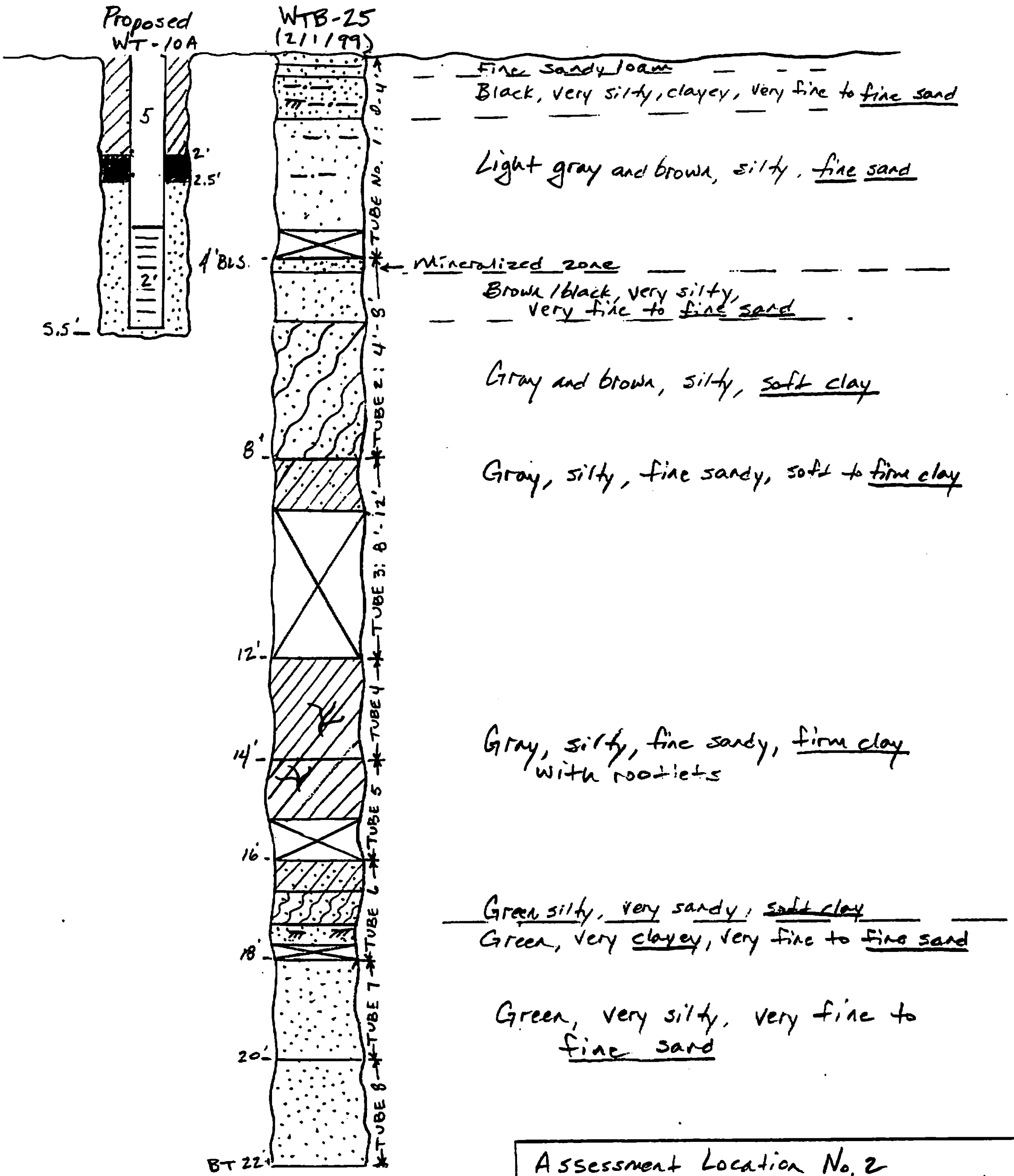
GREEN W/ ZONES OF IRON STAINING, SILTY FINE TO VERY FINE SANDY GLAUCONITIC CLAY W/ WOOD FRAGMENTS.

GREEN, GLAUCONITIC SILTY FINE TO VERY FINE SAND. NO_3 < 10 ppm (?)

SAME AS ABOVE
GREEN, GLAUCONITIC SILTY FINE TO VERY FINE SAND. NO_3 > 10 ppm < 50 ppm

GROUNDWATER SAMPLES:

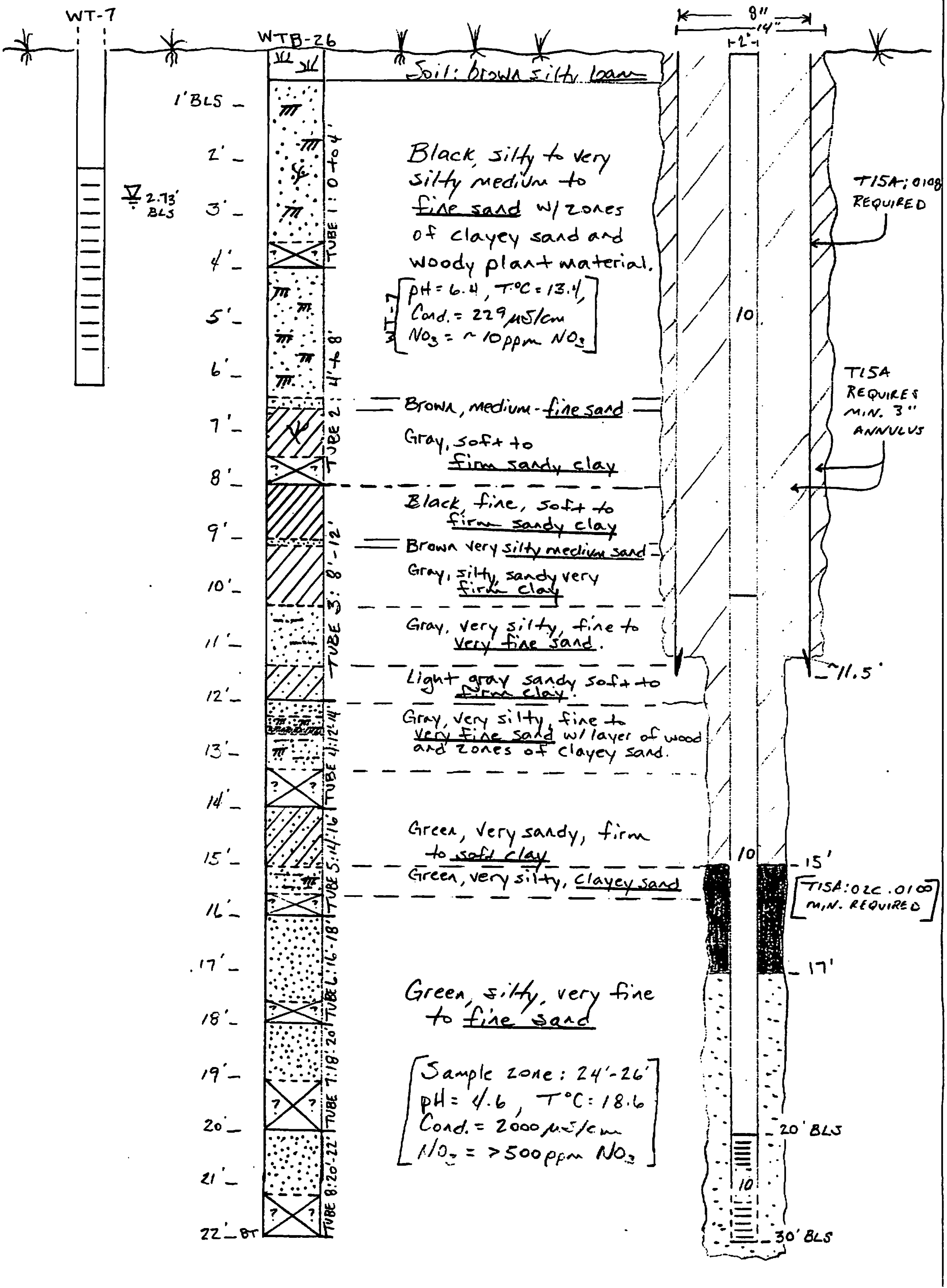
	T°C	pH	CONDUCTIVITY (µS/cm)	NO_3 (strip) ppm
WT-4	16.3	4.7	143	< 10
WTB-24	18.6	5.9	84	> 10 < 50



Assessment Location No. 2
Geoprobe Boring Data and Proposed Well
WT CaF2 Assessment
RTI Project 6443-019
Feb. 5, 1999 (J. Guthrie/J. Rabon)

Vert. Scale: 1" = 30'
All Measurements: Below Land Surface

GEOPROBE BORING: WT Assessment Area No. 3
2/1/99 (S. Guthrie)



Soil: brown silty loam

Black, silty to very silty medium to fine sand w/ zones of clayey sand and woody plant material.

WT-7
pH = 6.4, T°C = 13.4,
Cond. = 229 µS/cm
NO_3 = ~10 ppm NO_3

Brown, medium-fine sand

Gray, soft to firm sandy clay

Black, fine, soft to firm sandy clay

Brown very silty medium sand

Gray, silty, sandy very firm clay

Gray, very silty, fine to very fine sand.

Light gray sandy soft to firm clay.

Gray, very silty, fine to very fine sand w/ layer of wood and zones of clayey sand.

Green, very sandy, firm to soft clay

Green, very silty, clayey sand

Green, silty, very fine to fine sand

Sample zone: 24'-26'
pH = 4.6, T°C: 18.6
Cond. = 2000 µS/cm
NO_3 = >500 ppm NO_3

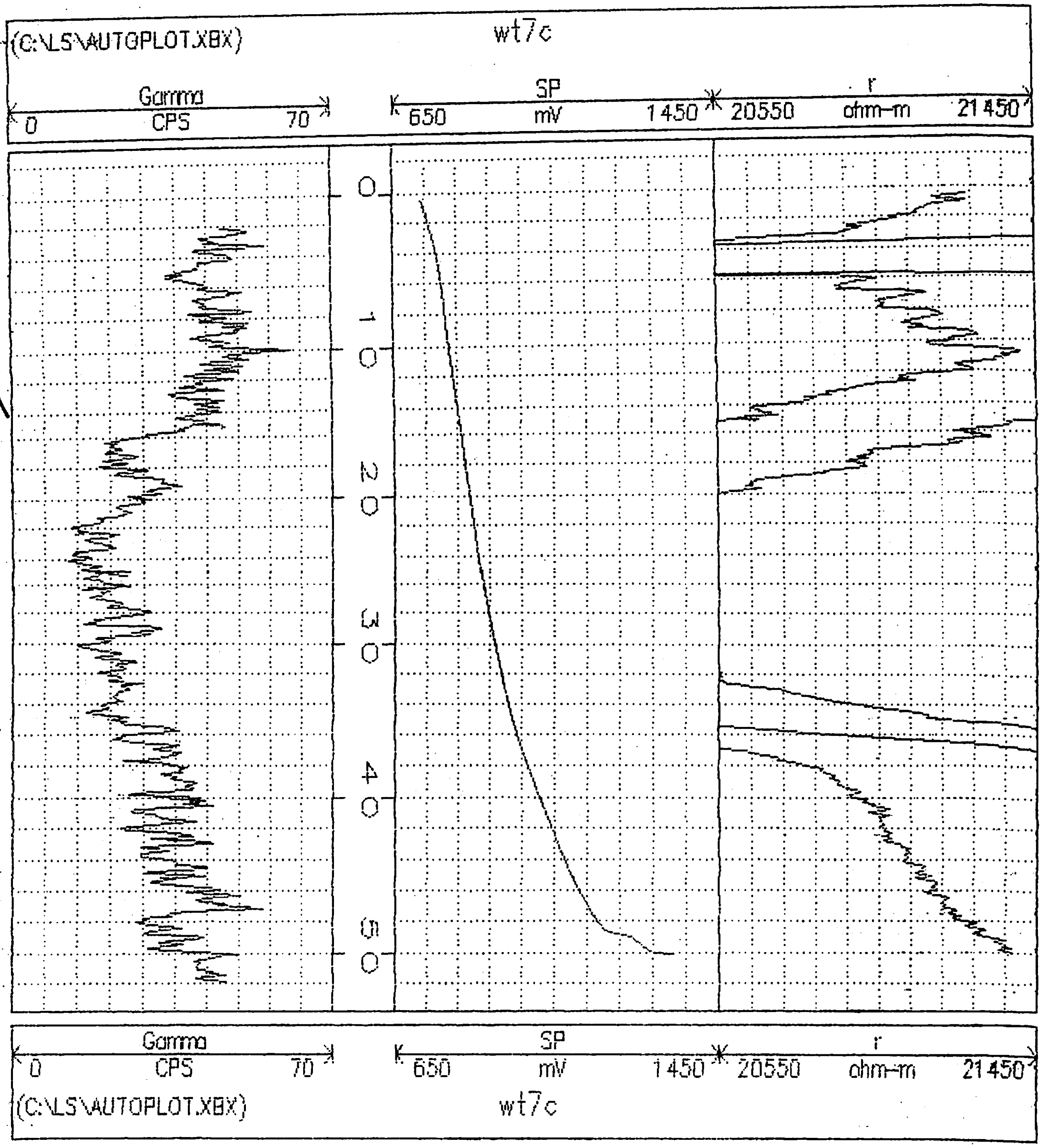
TISA; 0108 REQUIRED

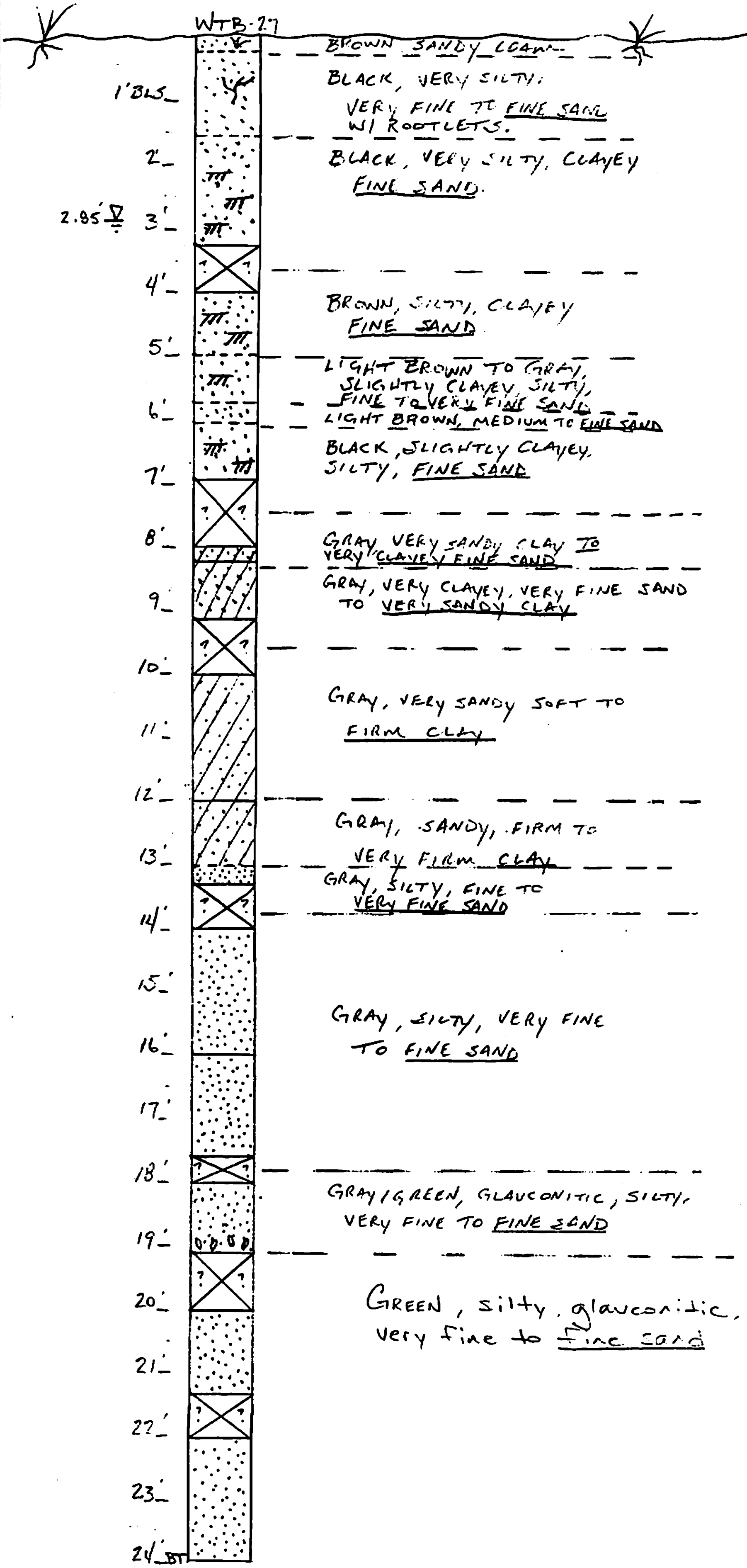
TISA REQUIRES MIN. 3" ANNULUS

TISA: 02C .0100 MIN. REQUIRED

Dek Barrows
Sandy ORGANIC
S.H

shelly
intervals





BROWN SANDY LOAM

BLACK, VERY SILTY: VERY FINE TO FINE SAND W/ ROOTLETS.

BLACK, VERY SILTY, CLAYEY FINE SAND.

BROWN, SILTY, CLAYEY FINE SAND

LIGHT BROWN TO GRAY, SLIGHTLY CLAYEY, SILTY, FINE TO VERY FINE SAND

LIGHT BROWN, MEDIUM TO FINE SAND

BLACK, SLIGHTLY CLAYEY, SILTY, FINE SAND

GRAY, VERY SANDY CLAY TO VERY CLAYEY FINE SAND

GRAY, VERY CLAYEY, VERY FINE SAND TO VERY SANDY CLAY

GRAY, VERY SANDY SOFT TO FIRM CLAY

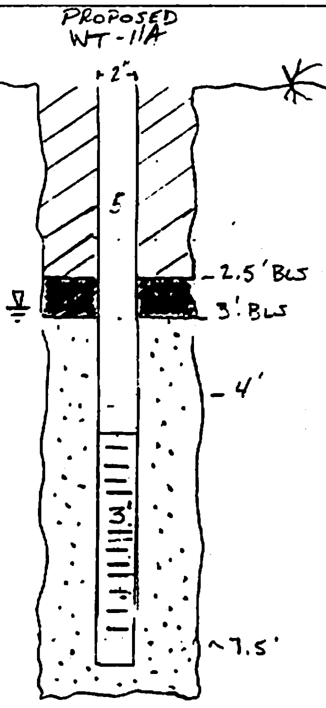
GRAY, SANDY, FIRM TO VERY FIRM CLAY

GRAY, SILTY, FINE TO VERY FINE SAND

GRAY, SILTY, VERY FINE TO FINE SAND

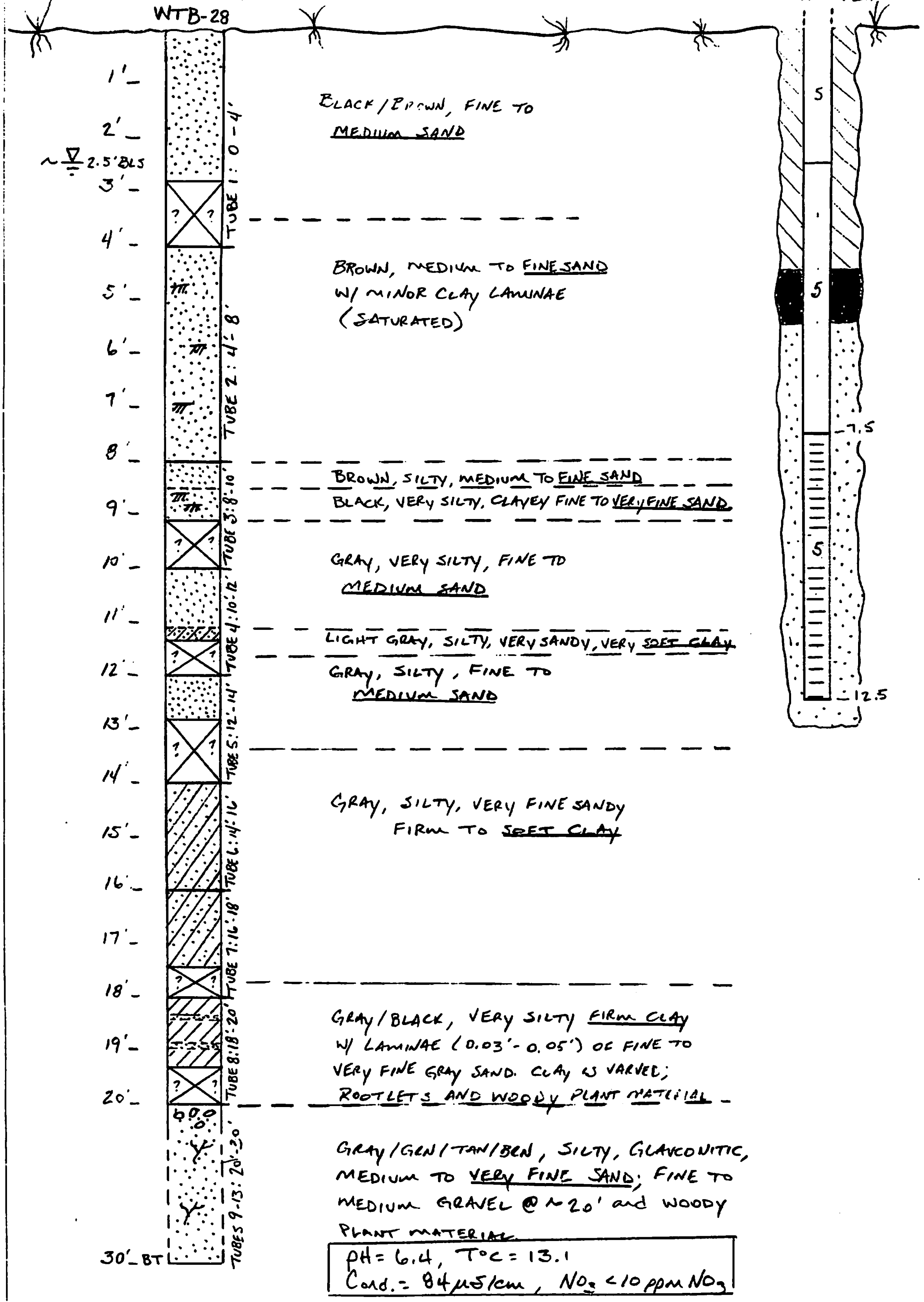
GRAY/GREEN, GLAUCONITIC, SILTY, VERY FINE TO FINE SAND

Green, silty, glauconitic, very fine to fine sand



GEOPROBE BORING
WT ASSESSMENT AREA 4
1/27/99
S. GUTHRIE

GEOPROBE BORING: WT ASSESSMENT AREA 5
1/26/99 (S. GUTHRIE)



BLACK/BROWN, FINE TO MEDIUM SAND

BROWN, MEDIUM TO FINE SAND W/ MINOR CLAY LAMINAE (SATURATED)

BROWN, SILTY, MEDIUM TO FINE SAND

BLACK, VERY SILTY, CLAYEY FINE TO VERY FINE SAND

GRAY, VERY SILTY, FINE TO MEDIUM SAND

LIGHT GRAY, SILTY, VERY SANDY, VERY SOFT CLAY

GRAY, SILTY, FINE TO MEDIUM SAND

GRAY, SILTY, VERY FINE SANDY FIRM TO SOFT CLAY

GRAY/BLACK, VERY SILTY FIRM CLAY W/ LAMINAE (0.03'-0.05') OF FINE TO VERY FINE GRAY SAND. CLAY IS VARVED; ROOTLETS AND WOODY PLANT MATERIAL

GRAY/GRN/TAN/BRN, SILTY, GLAUCONITIC, MEDIUM TO VERY FINE SAND; FINE TO MEDIUM GRAVEL @ ~20' and WOODY PLANT MATERIAL

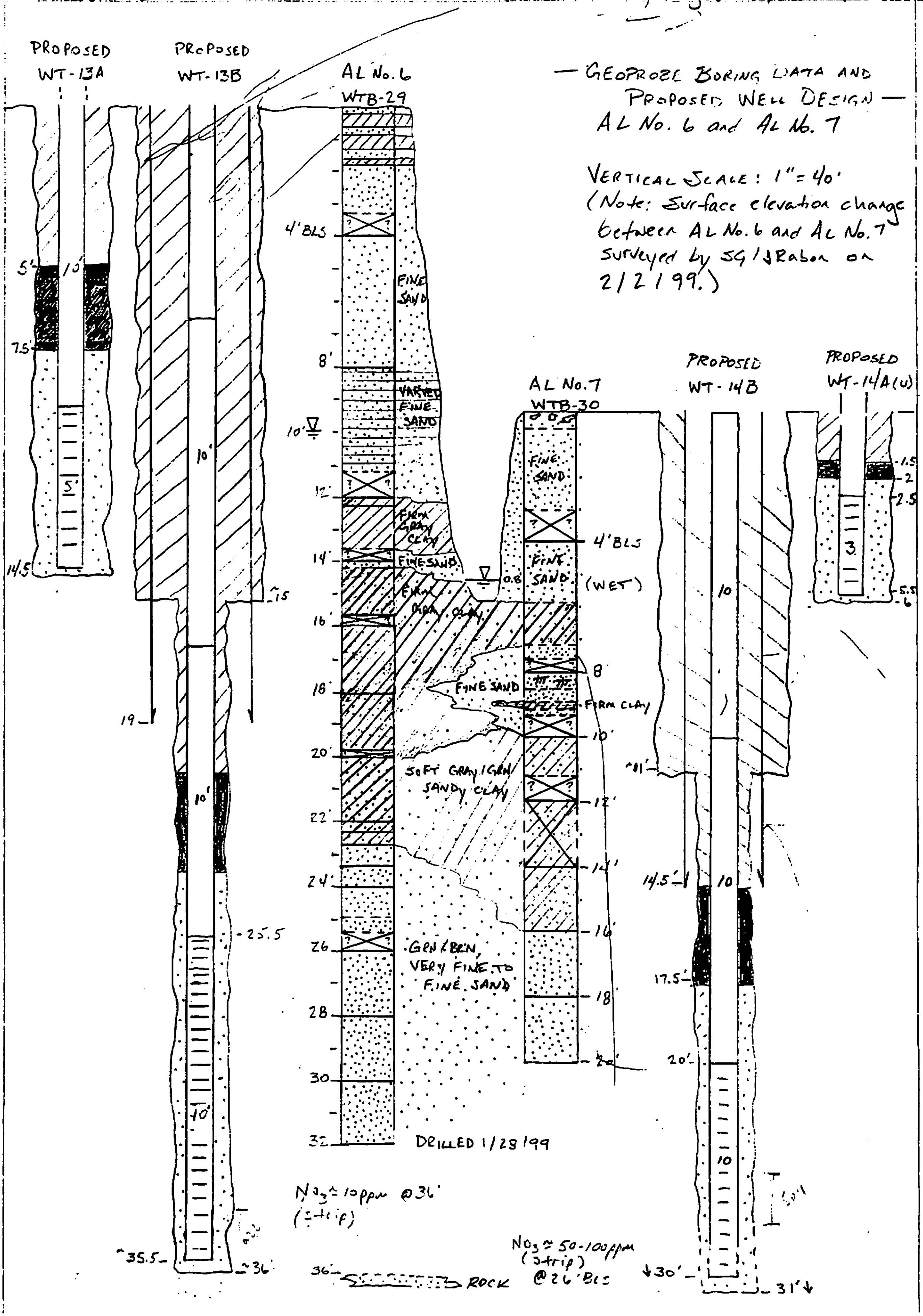
pH = 6.4, T°C = 13.1
Cond. = 84 µS/cm, NO_3 < 10 ppm NO_3

J. Guthrie

WT Lake Assessment
P-T-J Project 6448-019

— GEOPROBE BORING DATA AND PROPOSED WELL DESIGN —
AL No. 6 and AL No. 7

VERTICAL SCALE: 1" = 4'
(Note: Surface elevation change between AL No. 6 and AL No. 7 surveyed by SG/JRabon on 2/2/99.)



☑ BORING
☐ EXCAVATION

FIELD LITHOLOGIC LOG

SITE NAME AND LOCATION Waste Treatment Area - W side 50% Between WT-7B & WT-13B c. 60' East of N-S Channel	PROJECT NO. 6498-019	BORING / EXCAVATION NO. WTB-31
DRILLING CONTRACTOR Skipper Well Drilling	DRILLING METHOD Direct Push	SHEET 1 OF 4
DRILLER R. Skipper	SAMPLING METHOD Soils - Direct Push Water - Screen PT 15 Groundwater Sampler	DRILLING START TIME 09:00 FINISH TIME 16:30
DRILLER S. Parrish		
GEOLOGIST C. Keith	WEATHER 30's-40's - cloudy/rain - NW 15-20	START DATE 3-9-99 FINISH DATE 3-9-99
DRILL RIG Concord 9200	SURFACE CONDITIONS improved grade	
ANGLE Vert. / BEARING —		
DATUM Land Surface / ELEVATION —	COORDINATES —	

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
0.0				0.0-1.0 - Dark Blackish Brown organic silty sand								
1.0	0.0	4.0	Soils #1	1.0-1.1 - Light Grey/orange mottled silty (clay)								
				1.1-1.5 - Dark Brownish Black slightly sandy silt								
				1.5-2.1 - Medium Brown silty VF sand		81%						
2.0				2.1-2.3 - Dark Brownish Black slightly sandy silt - organic/root mtl.								
				2.3-2.6 - Black/light Brown speckled silty VF sand								
3.0				2.6-3.24 - Very Dark Blackish Brown sandy silt								
4.0	4.0	8.0	Soils #2	4.0-6.2 - Medium Brown silty sand - gradational into —		95%						
5.0												
6.0				6.2-6.8 - Medium Brown moist sand with upper Dark Brown silty stringer								
7.0				6.8-7.1 - Medium Reddish Brown VF sand with dark Brown silty stringers								
8.0												

BORING TERMINATED AT 30.0 FT BLS. LOGGED BY: C. Keith

COMMENTS:

☑ BORING
☐ EXCAVATION

FIELD LITHOLOGIC LOG

SITE NAME AND LOCATION Waste Treatment Area - in line 50% Between WT-7B & WT-8B & 60' East of N-S Channel	PROJECT NO. 6448-019	BORING / EXCAVATION NO. WTB-31
DRILLING CONTRACTOR Skipper Well Drilling	DRILLING METHOD Direct Push	SHEET 2 OF 4
DRILLER R. Skipper	SAMPLING METHOD Soils - Direct Push Water - Screen PTIS Groundwater Sample	DRILLING START TIME 09:00 DATE 3-9-99 FINISH TIME 16:30 DATE 3-9-99
DRILLER S. Parrish		
GEOLOGIST C. Keith	WEATHER 30's - 40's - Cloudy/Rain - NW 15-20	
DRILL RIG Concord 9200	SURFACE CONDITIONS improved Grade	
ANGLE Vert.	BEARING —	
DATUM Land Surface	ELEVATION —	COORDINATES —

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
8.0	8.0 to 12.0		Soils #3	8.0 - 11.0 - Brownish red moist F-vF Sand		75%						
9.0												
10.0												
11.0												
12.0	12.0 to 14.0		Soils #4	12.0 - 12.25 - Saturated Brown vF Sand med pink [illegible] 12.25 - 12.65 - Dark Blackish Brown Organic Silty Sand 12.65 - 13.0 - Dark Brownish Grey Sandy Clay		52%						
13.0												
14.0	14.0 to 16.0		Soils #5	14.0 - 14.9 - Stiff Greenish Grey Clay Gradational into — 14.9 - 16.0 - Medium Brown Clayey vF Sand		100%						
15.0												
16.0												

BORING TERMINATED AT 30.0 FT BLS. LOGGED BY: C. Keith

COMMENTS:

☑ BORING
☐ EXCAVATION

FIELD LITHOLOGIC LOG

SITE NAME AND LOCATION Waste Treatment AReA W Line 50% Between WT-7B & WT-BB c. 60' East of N-S Channel	PROJECT NO. 6448-019	BORING / EXCAVATION NO. WTB-31
DRILLING CONTRACTOR Skipper Well Drilling	DRILLING METHOD Direct Push	SHEET 3 OF 4
DRILLER R. Skipper	SAMPLING METHOD Soils - Direct Push Water - Screen PT15 Groundwater Sampler	DRILLING START TIME 09:00 — FINISH TIME 16:30
DRILLER S. Parrish		
GEOLOGIST C. Keith	WEATHER 30's-40's - cloudy, rain - NW20	START DATE 3-9-99 — FINISH DATE 3-9-99
DRILL RIG Concord 9200	SURFACE CONDITIONS improved grade	
ANGLE Vert. — BEARING —		
DATUM Land Surface — ELEVATION —	COORDINATES —	

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
16.0	16.0	18.0	Soils #6	16.0-16.7- Greyish Brown to Brown Sandy Clay Gradational into —		93%						
17.0				16.7-17.65- Med Brown VF to Fine Sand - Sharp contact into grey VF Sand								
18.0	18.0	20.0	Soils #7	18.0-19.2- Saturated Grey VF Sand		100%						
19.0				19.2-20.0 - Grey slightly Sandy clay with organic/ Root mtl.								
20.0	20.0	22.0	Soils #8	20.0-20.4 - Greenish Grey slightly clayey VF Sand		75%						
21.0				20.4-21.5- Greenish Grey VF Sand with organic/ Root mtl.								
22.0	22.0	24.0	Soils #9	22.0-23.7- Saturated Greenish Grey VF Sand with organics		100%						
23.0				23.7-24.0 - Orange and Grey mottled VF Sand								
24.0												

BORING TERMINATED AT 30.0 FT BLS. LOGGED BY: C. Keith

COMMENTS:

☑ BORING
☐ EXCAVATION

FIELD LITHOLOGIC LOG

SITE NAME AND LOCATION Waste Treatment Area In Line 50% Between WT-7B : WT 1B3 c. 60' East of D-5 Channel	PROJECT NO. 6448-019	BORING / EXCAVATION NO. WTB-31
DRILLING CONTRACTOR Skipper Well Drilling	DRILLING METHOD Direct Push	SHEET 4 OF 4
DRILLER R. Skipper		DRILLING START TIME / FINISH TIME
DRILLER S. Parrish	SAMPLING METHOD Soils – Direct Push Water – Screen PT15 Groundwater Sampler	
GEOLOGIST C. Keith	WEATHER 30's-40's – Cloudy, Rain – Nw 15-20	DATE / DATE
DRILL RIG Concord 9200	SURFACE CONDITIONS improved grade	
ANGLE Vert. / BEARING —		
DATUM Land Surface / ELEVATION —	COORDINATES —	

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
24.0 25.0	24.0	26.0	Soils #10	24.0 – 26.0 – yellowish Greenish Grey VF Saturated Sand	⁘	100%						
26.0 27.0	26.0	28.0	Soils #11	26.0 – 26.7 – Green VF Saturated Sand 26.7 – 27.9 – Dark orangish tan VF Saturated Sand	⁘	95%						
28.0 29.0	28.0	30.0	Soils #12	28.0 – 28.4 – Greenish Tan VF Saturated Sand	⁘	20%					unfiltered	Water Samples – F/NO_3 – 13708 (CHn 1.63/2270 Ammonia – 13707 (C 69.306 Trace U – 13709 (CHne 0.0366
30.0												Field Parameters. NO_3 Strips = 7500 Conductivity = 1535 pH = 4.69 Temp = 16.9°C

BORING TERMINATED AT 30.0 FT BLS.   LOGGED BY: C. Keith

COMMENTS:

☑ BORING
☐ EXCAVATION

FIELD LITHOLOGIC LOG

SITE NAME AND LOCATION C. 400' West of MW-14 & South 180'	PROJECT NO. 6448-019	BORING / EXCAVATION NO. WTB-32
DRILLING CONTRACTOR Skipper Well Drilling	DRILLING METHOD Direct Push	SHEET 1 OF 5
DRILLER R. Skipper	SAMPLING METHOD Soils - Direct Push Water - Screen PT 15 Groundwater Sampler	DRILLING START TIME 18:30 / FINISH TIME 12:30
DRILLER S. Parrish		
GEOLOGIST C. Keith	WEATHER 40's - cloudy - P (W) - 5-25	START DATE 3-10-99 / FINISH DATE 3-11-99
DRILL RIG Concord 9200	SURFACE CONDITIONS Graded	
ANGLE Vert. / BEARING —		
DATUM Land Surface / ELEVATION —	COORDINATES —	

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
0.0				0.0 - 0.9 - Black silty organic Sand								
1.0	0.0 to 4.0		Soils #1	0.9 - 1.1 - Brownish Gray VF Sand								
				1.6 - 1.7 - Black Organic Sandy Silt. - Gradational into -		100%						
2.0 3.0				1.7 - 4.0 - Medium Brown VF Sand - Some oxidation - some slightly saturated zoned								
4.0				4.0 - 4.5 - Orangish Brown silty F - VF Sand								
				4.5 - 4.8 - Black Sandy organic silt / Roots								
5.0	4.0 to 8.0		Soils #2	4.8 - 6.2 - Dark Grayish Brown slightly silty sand gradational into saturated zone		81%						
6.0 7.0				6.2 - 7.5 - Brownish Red saturated VF Sand								Nitrate Strip At 7.0 = 0
8.0												

BORING TERMINATED AT 37.1 FT BLS.　　LOGGED BY: C. Keith

COMMENTS:

☑ BORING
☐ EXCAVATION

FIELD LITHOLOGIC LOG

SITE NAME AND LOCATION c. 400' west of WW-14 & South 180'
PROJECT NO. 6448-019
BORING / EXCAVATION NO. WTB-32
DRILLING CONTRACTOR Skipper Well Drilling
DRILLING METHOD Direct Push
SHEET 2 OF 5
DRILLER R. Skipper
SAMPLING METHOD Soils – Direct Push; Water – Screen PT 15 – Groundwater Sampler
DRILLER S. Parrish
GEOLOGIST C. Keith
WEATHER 40's – cloudy – NW 5-25
DRILLING START TIME 08:30 DATE 3-10-99; FINISH TIME 12:30 DATE 3-11-99
DRILL RIG Concord 9200
SURFACE CONDITIONS Graded
ANGLE Vert.
BEARING —
DATUM Land Surface
ELEVATION —
COORDINATES —

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
8.0	8.0	10.0	Water #1									Pushed with Screen to 14.0 for water sample No yield on water – Nitrate Strip = 0
9.0												
10.0	10.0	12.0	Soil #3	10.0 – 10.7 – Stiff Gray Clay		100%						
11.0				10.7 – 11.4 – Sandy Gray Clay								
				11.4 – 12.0 – Light Gray VF Sand								
12.0	12.0	14.0	Water #2	Field Parameters – Conductivity = 147.4 Temp = 13.2 °C Nitrate Strip = 0 pH = 5.9								Filtered – Ammonia – 13711 – Chemist 1.628 F/NO3 – 13712 – Chemist <1/0.280 Trace U – 13713 – Chemist <0.02
13.0												
14.0						0%						
15.0												
16.0												

BORING TERMINATED AT 37.1 FT BLS.
LOGGED BY: C. Keith
COMMENTS:

☑ BORING
☐ EXCAVATION

FIELD LITHOLOGIC LOG

SITE NAME AND LOCATION C. 400' West of OW-14 ; South 180'	PROJECT NO. 6448-019	BORING / EXCAVATION NO. WTB-32
DRILLING CONTRACTOR Skipper Well Drilling	DRILLING METHOD Direct Push	SHEET 3 OF 5
DRILLER R. Skipper	SAMPLING METHOD Soils - Direct Push	DRILLING START TIME 08:30 / FINISH TIME 12:30
DRILLER S. Parrish	Water - Screen PTR - Groundwater Sampler	
GEOLOGIST C. Keith	WEATHER 40's - cloudy - NW-5-25	START DATE 3-10-99 / FINISH DATE 3-11-99
DRILL RIG Concord 9200	SURFACE CONDITIONS Graded	
ANGLE Vert. / BEARING —		
DATUM Land Surface / ELEVATION —	COORDINATES —	

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
16.0 17.0	16.0 to 18.0		Soils #4	16.0 - 17.6 - Green Glauconitic stiff sandy clay 17.6 - 18.0 - light greenish gray VF Sand		100%						Nitrate strip at 18.0 = 0
18.0 19.0	18.0 to 20.0		Water #3	Dry								Nitrate strip at 20.0 = 0
20.0 21.0	20.0 to 22.0		Soils #5	20.0 to 22.0 - Very Fine green glauconitic Sand		100%						
22.0 23.0	22.0 to 24.0		Water #4	Dry								
24.0												

BORING TERMINATED AT 37.1 FT BLS. LOGGED BY: C. Keith

COMMENTS:

☑ BORING
☐ EXCAVATION

FIELD LITHOLOGIC LOG

SITE NAME AND LOCATION C. 400' West of WU-14 & South 180'
PROJECT NO. 6448-019
BORING / EXCAVATION NO. WTB-32
DRILLING CONTRACTOR Skipper Well Drilling
DRILLING METHOD Direct Push
SHEET 4 OF 5
DRILLER R. Skipper
SAMPLING METHOD Soil - Direct Push
Water - Screen Pt 15 Groundwater Sampler
DRILLER S. Parrish
DRILLING START TIME 08:30 FINISH TIME 12:30
GEOLOGIST C. Keith
WEATHER 40's - Cloudy - NW 5-25
START DATE 3-10-99 FINISH DATE 3-11-99
DRILL RIG Concord 9200
SURFACE CONDITIONS Graded
ANGLE Vert.
BEARING —
DATUM Land Surface
ELEVATION —
COORDINATES —

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
24	24.0 to	26.0	Soil #6	24.0 - 25.3 - Saturated Green Glauconitic VF Sand		65%						
25												
26	26.0 to	28.0	Water #5	Field Parameters— pH = 5.0 Conductivity = 528.0 Temp = 16.7 - Nitrate = 0								filtead— 13717 - Ammonia = .3 13718 - F/NO_3 = <1/<.02 13719 - U = <0.02 Un Filt = 13714 = 10.3[illegible]2 13715 = <1/0.[illegible]0 13716 = <0.02
27												
28	28.0 to	30.0	Soil #7	28.0 - 29.5 - Dark Greenish Grey Saturated VF Sand		75%						
29												
30	30.0 to	32.0	Water #6	Field parameters— pH = 5.4 Conductivity = 232.9 Temp = 15.9 °C Nitrate Strip = 0								Unfiltered= Ammonia - 13720 = 0.72 F/NO_3 - <1/0.652 Trace U - 13729 - <.0 Filtered— Ammonia - 13721 - <.4 F/NO_3 - 13723 - <1/< Trace U 1372[illegible] - <.0
31												
32												

BORING TERMINATED AT 37.1 **FT BLS.** **LOGGED BY:** C. Keith

COMMENTS:

☑ BORING
☐ EXCAVATION

FIELD LITHOLOGIC LOG

SITE NAME AND LOCATION C. 400' west of ww-14 C. 180' South	PROJECT NO. 6448-019	BORING / EXCAVATION NO. WTB-32
DRILLING CONTRACTOR Skipper Well Drilling	DRILLING METHOD Direct Push	SHEET 5 OF 5
DRILLER R. Skipper	SAMPLING METHOD soils – Direct Push water – ScreenPT15 Groundwater Sampler	DRILLING START TIME 08:30 DATE 3-10-98; FINISH TIME 12:30 DATE 3-11-98
DRILLER S. Parrish	WEATHER 40's – cloudy – NW-5-25	
GEOLOGIST C. Keth		
DRILL RIG Concord 9200	SURFACE CONDITIONS Graded	
ANGLE Vert. / BEARING —		
DATUM Land Surface / ELEVATION —	COORDINATES —	

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
32	32.0 to 34.0		Soil #8	32.0–33.1 – Dark Greenish Gray Glauconitic VF Silty Sand		0.56						
33												
24	34.0 to 36.0		Water #7	Field Parameters: pH = 5.6 Conductivity = 287.7 Temp = 16.5°C Nitrate Strip = 0								Unfiltered – 13726 – Ammonia – 0.6 13728 – F/NO3 – <1/ 13734 – U – <0.02 Filtered – 13727 – Ammonia – <. 13729 – F/NO3 <1/ 13735 – U – <0.02
35												
36	36.0 to 32.1		Soil #9	36.0–37.1 – Green Glauconitic VF Sand w/ calcareous sandstone & shell mtl		55%						
37												
38												
39												
40												

BORING TERMINATED AT 37.1 FT BLS. LOGGED BY: C. Keth

COMMENTS:

FIELD LITHOLOGIC LOG

☐ EXCAVATION

SITE NAME AND LOCATION Waste Treatment – 7.8' west of WT-7B
PROJECT NO. 6448-019
BORING / EXCAVATION NO. WTB-33
DRILLING CONTRACTOR Skipper Well Drilling
DRILLING METHOD Direct Push
SHEET 1 OF 4
DRILLER R. Skipper
DRILLER S. Parrish
SAMPLING METHOD soils – Direct Push; water – Screen PT 15 Groundwater Sampler

	DRILLING	
	START	FINISH
TIME	09:10	16:45
DATE	3-15-99	3-15-99

GEOLOGIST C. Keith
WEATHER Spitting cold-30-50-NW25-cloudy Rain
DRILL RIG Concord 9200
SURFACE CONDITIONS unpaved road
ANGLE Vert.
BEARING —
DATUM Land Surface
ELEVATION —
COORDINATES —

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
0.0				0.0-0.20 - Light tan med-fine Fill Sand								
				0.20-1.40 - Brownish Black slightly sandy organic silt with wood mtl.								
1.0	0.0	4.0	Soils #1	1.4-2.0 - Brownish Black slightly sandy organic silt w/ wood mtl & med grey clay stringers		90%						
2.0				2.0-3.6 - First .15 med gray stiff clay to Brownish Black slightly sandy organic silt with wood mtl. & med gray clay stringers								
3.0												
4.0				4.0-5.0 - Brownish Black slightly sandy organic silt/wood mtl/ med gray clay stringers								
5.0				5.0-5.4 - med gray stiff clay								
	4.0	8.0	Soils #2	5.4-6.4 - Saturated drk Brownish Black silt sandy		88%						
6.0				6.4-7.5 - Med gray sandy clay to stiff clay								
7.0												
8.0												

BORING TERMINATED AT 30.0 **FT BLS.** **LOGGED BY:** C. Keith

COMMENTS:

☐ EXCAVATION

FIELD LITHOLOGIC LOG

SITE NAME AND LOCATION Waste Treatment 7.8' West of WT-7B	PROJECT NO. 6448-019	BORING / EXCAVATION NO. WTB-33
DRILLING CONTRACTOR Skipper Well Drilling	DRILLING METHOD Direct Push	SHEET 2 OF 4
DRILLER R. Skipper	SAMPLING METHOD soils - Direct Push Water - Screen PT 15 Groundwater Sampler	DRILLING START TIME 09:10 / FINISH TIME 16:45
DRILLER S. Parrish		
GEOLOGIST C. Keith	WEATHER Cold-Cold-Cold-NW 25-cloud/rain	START DATE 3-15-99 / FINISH DATE 3-15-99
DRILL RIG Concord 9200	SURFACE CONDITIONS unpaved grade	
ANGLE Vert. / BEARING —		
DATUM Land Surface / ELEVATION —	COORDINATES —	

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
8.0				8.0-8.5 - Saturated Black/Brown silty VF Sand								Attempt at H2O Sample from 8.0-10.0 = Dry Nitrate = 0
9.0	8.0	to 12.0	Soils #3	8.5-10.0 - Moist Med. Brown F-VF Sand		100%						Moved North 0.5'
10.0				10.0-12.0 - Light grey clayey VF Sand-/Clay sparse coarse grains								Set 4' Core Sample 8.0-12.0
11.0												Nitrate-soils @ 9.0 = 0 Nitrate soils @ 11 = 0
12.0	12.0	to 14.0	Soils #4	12.0-13.1 - Med gray VVF moist sand - silty		55%						Nitrate strip @ 13.0 = 0
13.0												
14.0	14.0	to 16.0	Soils #5	14.0-16.1 - Med Grey VF to silty moist sand (to saturated) some clay platelets		90%						Nitrate at 14.5 = 0 Nitrate @ 16.0 = 0
15.0				15.1-15.8 - Green VF Sand wood mtl.- moist								
16.0												

BORING TERMINATED AT 30.0 FT BLS. LOGGED BY: C. Keith

COMMENTS:

☐ EXCAVATION

SITE NAME AND LOCATION Waste Treatment 7.8' West of WT-7B	PROJECT NO. 6448-019	BORING / EXCAVATION NO. WTB-33
DRILLING CONTRACTOR Skipper Well Drilling	DRILLING METHOD Direct Push	SHEET 3 OF 4
DRILLER R. Skipper	SAMPLING METHOD Soil - Direct Push	DRILLING START TIME 09:10 / FINISH TIME 16:45
DRILLER S. Parrish	Water - Screen PT 15 Groundwater Sampler	
GEOLOGIST C. Keith	WEATHER none than cold - NW 25 -	START DATE 3-15-99 / FINISH DATE 3-15-99
DRILL RIG Concord 9200	SURFACE CONDITIONS improved grade	
ANGLE Vert. / BEARING —		
DATUM Land Surface / ELEVATION —	COORDINATES —	

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
16.0												
17.0	17.0 to 19.0		Water #1									Water Sample pH - Field = 3.9 Conductivity = 1402 Temp = 17.0°C Nitrate Strip = 250-500
18.0												
19.0												
20.0	20.0 to 22.0		Water #2									Water Sample pH = 4.5 Conductivity 1252 Temp = 16.7°C Nitrate Strip = 500
21.0												
22.0												
23.0	23.0 to 25.0		Water #3									Water Sample pH = 4.8 Conductivity = 745 Temp = 17.1°C - Nitrate
24.0												

BORING TERMINATED AT 30.0 FT BLS.   LOGGED BY: C. Keith

COMMENTS:

☐ EXCAVATION

FIELD LITHOLOGIC LOG

SITE NAME AND LOCATION Waste Treatment 7.8' West of WT-7 B	**PROJECT NO.** 6446-019	**BORING / EXCAVATION NO.** WTB-33
DRILLING CONTRACTOR Skipper Well Drilling	**DRILLING METHOD** Direct Push	**SHEET** 4 OF 4
DRILLER R. Skipper	**SAMPLING METHOD** Soils - Direct Push water - Screen PT & Grab Water Sampler	**DRILLING** START TIME 08:10 DATE 3-15-98 / FINISH TIME 16:45 DATE 3-15-98
DRILLER S. Parrish		
GEOLOGIST C. Keith	**WEATHER** Cold - Don't Ask	
DRILL RIG Concord 9200	**SURFACE CONDITIONS** improved Grade	
ANGLE Vert. / **BEARING** —		
DATUM Land Surface / **ELEVATION** —	**COORDINATES** —	

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
24.0												
25.0												
26.0												
27.0												
28.0	28.0 to 30.0		WATER #1									Temp= 17.1°C Conductivity= 307.4 pH= 6.2 Nitrate strip= 50
29.0												
30.0												

BORING TERMINATED AT 30.0 FT BLS.

LOGGED BY: C. Keith

COMMENTS:

☐ EXCAVATION

FIELD LITHOLOGIC LOG

SITE NAME AND LOCATION Waste Treatment Inside WT Fence on SE Dike Corner	PROJECT NO. 6448-019	BORING / EXCAVATION NO. WTB-34
DRILLING CONTRACTOR Skipper Well Drilling	DRILLING METHOD Direct Push	SHEET 1 OF 4
DRILLER R. Skipper	SAMPLING METHOD Soils - Direct Push Water - Screen PT15 Groundwater Sampler	DRILLING START TIME 09:30 FINISH TIME 14:15
DRILLER S. Parrish		
GEOLOGIST C. Keith	WEATHER 50-60 - Sunny - NW-5	START DATE 3-16-99 FINISH DATE 3-16-99
DRILL RIG Concord 9200	SURFACE CONDITIONS improved grade	
ANGLE Vert. BEARING —		
DATUM Land Surface ELEVATION —	COORDINATES —	

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
0.0				0.0 - 0.6 - Brownish-Black Organic Sandy Silt								
1.0 2.0 3.0	0.0 to 4.0		Soils #1	0.6 - 4.0 Dark Brown very Moist Silty VF Sand - Lightens Down & Coarsens Down to Bottom 0.6 medium Light Brown VF to Coarse Sand		100%						Nitrate strips At 2.0' & 4.0' BLS = 0
4.0				4.0-4.3 DRK Brown Fine-VF Moist Sand								Nitrate strip At 6.0 & 8.0' BLS = 0
5.0				4.3-5.1 Med to Lt. Brown Fine to Coarse Moist Sand								
	4.0 to 8.0		Soils #2 H_2O #1	5.1-6.0 Brownish Gray to Green Gray VF Saturated Sand		100%				5.0'	10:00 3-16-99	Water Sample From 6.0 - 8.0 pH = 5.5 Temp = 15.9°C Conductivity = 366.9 Nitrate strip = 0
6.0				6.0-6.2 - Greenish Gray Sandy Clay								
				6.2-7.2 - Greenish Gray Sandy Clay								
7.0				7.2-8.0 - Saturated Black Organic VF Sandy Silt								
8.0												

BORING TERMINATED AT 25.0 FT BLS. LOGGED BY: C. Keith

COMMENTS:

☑ BORING
☐ EXCAVATION

FIELD LITHOLOGIC LOG

SITE NAME AND LOCATION Waste Treatment inside WT Fence on SE Dike Corner	PROJECT NO. 6948-019	BORING / EXCAVATION NO. WTB-34
DRILLING CONTRACTOR Skipper Well Drilling	DRILLING METHOD Direct Push	SHEET 2 OF 4
DRILLER R. Skipper	SAMPLING METHOD Soils - Direct Push	DRILLING START TIME 09:30 / FINISH TIME 14:15
DRILLER S. Parrish	Water - Screen PT15 Groundwater Sampler	
GEOLOGIST C. Keith	WEATHER 50-60 - Sunny - NW 5	START DATE 3-16-99 / FINISH DATE 3-16-99
DRILL RIG Concord 9200	SURFACE CONDITIONS improved grade	
ANGLE Vert. / BEARING —		
DATUM Land Surface / ELEVATION —	COORDINATES —	

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
8.0	8.0	10.0	Soils #3	8.0-9.0 - Med Brown Slightly Clayey Silty F-VF Sand Saturated		59%						Nitrate strip At 9.0' BLS = 0
9.0				9.0-9.3 - Brownish gray clayey VF Sand moist								
				9.3-9.7 - Stiff Green Clay								
10.0	10.0	12.0	Soils #3	10.0-11.0 - Light Brownish gray very very fine moist Sand		50%						Nitrate strip at 11.0' = 0
11.0												
12.0	12.0	14.0	Soils #4	12.0-12.5 - Med Brownish Gray Clayey VF Sand								
13.0				12.5-14.0 - Drk Blackish Gray Loose Down to very Stiff Clay		100%						
14.0	14.0	16.0	Soils #4	14.0-14.8 - Saturated med. Brown F-VF Sand								Nitrate strip at 14.5' BLS = 0
15.0				14.8-16.0 - Stiff Green Clay with Root material		100%						
16.0												

BORING TERMINATED AT 25.0 FT BLS. LOGGED BY: C. Keith

COMMENTS:

FIELD LITHOLOGIC LOG

☐ EXCAVATION

SITE NAME AND LOCATION Waste Treatment Inside WT Fence on SE Dike Corner	PROJECT NO. 6498-019	BORING / EXCAVATION NO. WTB-34
DRILLING CONTRACTOR Skipper Well Drilling	DRILLING METHOD Direct Push	SHEET 3 OF 4
DRILLER R. Skipper	SAMPLING METHOD Soils - Direct Push Water - Screen PT 15 Groundwater Sampler	DRILLING START TIME 09:30 / FINISH TIME 14:15
DRILLER S. Parrish		
GEOLOGIST C. Keith	WEATHER 50-60 Sunny - NW 5	START DATE 3-16-99 / FINISH DATE 3-16-99
DRILL RIG Concord 9200	SURFACE CONDITIONS improved grade	
ANGLE Vert. / BEARING —		
DATUM Land Surface / ELEVATION —	COORDINATES —	

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
16.0	16.0	18.0	Soils #5	16.0 - 17.3 Stiff Green Clay with wood material		100%						Nitrate strip at 17.5' BLS = 0
17.0				17.3 - 18.0 - Brownish Gray slightly clayey very fine moist Sand								
18.0	18.0	20.0	Soils #6	18.0 - 18.7 - Clayey Dark Brown VF Sand - saturated		100%						
19.0				18.7 - 20.0 - Med to Dark grey moist VF slightly silty Sand with middle 0.5 solid wood material								
20.0												
21.0	21.0	23.0	H2O #2									Conductivity = 462.2 Temp = 20.2 °C pH = 4.4 Nitrate strip = 0
22.0												
23.0												
24.0												

BORING TERMINATED AT 25.0 FT BLS. LOGGED BY: C. Keith

COMMENTS:

☑ BORING
☐ EXCAVATION

FIELD LITHOLOGIC LOG

SITE NAME AND LOCATION Waste Treatment inside WT Fence on SE Dike Corner		PROJECT NO. 6448-019	BORING / EXCAVATION NO. WTB-34
DRILLING CONTRACTOR Skippen Well Drilling		DRILLING METHOD Direct Push	SHEET 4 OF 4
DRILLER R. Skippen		SAMPLING METHOD Soils - Direct Push Water - Screen PT15 Groundwater Sampler	DRILLING START TIME 09:30 / FINISH TIME 14:15
DRILLER S. Parrish			
GEOLOGIST C. Keith		WEATHER 50-60 - Sunny - NW5	START DATE 3-16-99 / FINISH DATE 3-16-99
DRILL RIG Concord 9200		SURFACE CONDITIONS improved grade	
ANGLE Vert.	BEARING —		
DATUM Land Surface	ELEVATION —	COORDINATES	

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
24.0	24.0 to 25.0		H_2O #3									Conductivity = 240.5 Temp = 19.5 pH = 5.0 Nitrate strip = 0
25.0				Hard shelly sandstone Below 25.0' BLS								

BORING TERMINATED AT 25.0 FT BLS. LOGGED BY: C. Keith

COMMENTS:

FIELD LITHOLOGIC LOG

☑ BORING
☐ EXCAVATION

SITE NAME AND LOCATION 4' N Waste Treatment/Next to WTB-31	PROJECT NO. 6948-019	BORING / EXCAVATION NO. WTB-35	
DRILLING CONTRACTOR Skipper Well Drilling	DRILLING METHOD Geoprobe Direct Push	SHEET 1 OF 5	
DRILLER R. Skipper	SAMPLING METHOD Packer/Peristaltic	DRILLING START TIME 10:50	FINISH TIME 14:50
DRILLER S. Parrish			
GEOLOGIST C. Keith	WEATHER Sunny - 70s	DATE 6-23-99	DATE 6-23-99
DRILL RIG Concord 9200	SURFACE CONDITIONS improved grade		
ANGLE Vert.	BEARING —		
DATUM Land Surface	ELEVATION 30.10 See WTB-31	COORDINATES C. 5310.0 N/13,268.0E	Based on WTB-31

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
0.0												
1.0												
2.0												
3.0												
4.0												
5.0				See WTB-31 For Lithology								
6.0												
7.0												
8.0												

BORING TERMINATED AT 34.0 FT BLS.   LOGGED BY: C. Keith

COMMENTS:

☑ BORING
☐ EXCAVATION

FIELD LITHOLOGIC LOG

SITE NAME AND LOCATION Waste Treatment (next to WTB-31 1' N	PROJECT NO. 6998-019	BORING / EXCAVATION NO. WTB-35
DRILLING CONTRACTOR Skipper Well Drilling	DRILLING METHOD Geoprobe Direct Push	SHEET 2 OF 5
DRILLER R. Skipper	SAMPLING METHOD Probe / Peristaltic	DRILLING START TIME 10:50 FINISH TIME 14:50
DRILLER S. Parrish		
GEOLOGIST C. Keith	WEATHER Sunny - 70's - 80's	START DATE 6-23-99 FINISH DATE 6-23-99
DRILL RIG Concord 9200	SURFACE CONDITIONS improved grade	
ANGLE Vert.	BEARING —	
DATUM Land Surface	ELEVATION 30.10 Based on WTB-31	COORDINATES Q.5310.0 N / 13,268.0 E Based on WTB-31

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
8.0												
9.0				See WTB-31 Log								
10.0												
11.0				(Elev - 18.10)								
12.0	10.0	12.0		Sample Attempt @ 12.0 - Dry								
130				See WTB-31 Log								
14.0				(Elev - 14.10)								
15.0			D20923/20924	Field Analysis 14.0 - 16.0 pH = 4.7 - NO_3 = 0 Chemet Analysis - NH_3 = 0.75 ppm - NO_3 = <0.2								
160	14.0	16.0										Acrid odor

BORING TERMINATED AT 34.0 FT BLS. LOGGED BY: C. Keith

COMMENTS:

☑ BORING
☐ EXCAVATION

FIELD LITHOLOGIC LOG

SITE NAME AND LOCATION 4' N Waste Treatment / Next to WTB-31	PROJECT NO. 6448-019	BORING / EXCAVATION NO. WTB-35
DRILLING CONTRACTOR Skipper Well Drilling	DRILLING METHOD Geoprobe Direct Push	SHEET 3 OF 5
DRILLER R. Skipper	SAMPLING METHOD Probe/Peristaltic	DRILLING START TIME 10:50 / FINISH TIME 14:50
DRILLER S. Parrish		
GEOLOGIST C. Keith	WEATHER sunny - 70's - 80's	START DATE 6-23-99 / FINISH DATE 6-23-99
DRILL RIG Concord 9200	SURFACE CONDITIONS improved grade	
ANGLE Vert BEARING —		
DATUM Land Surface ELEVATION 30.10 Based on WTB-31	COORDINATES C. 5810.0 N/18, 268.0 E	Based on WTB-81

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
16.0 17.0 18.0	17.0 to 19.0		2) 20425/20426	See WTB-31 Log (Elev = 11.1) Field analysis - 17.0-19.0 pH = 4.7 - NO_3 = 0 Chemet Analysis NH_3 - 0.987 ppm / NO_3 - <0.2								Low Volume Sulfur odor
19.0 20.0 21.0 22.0	21.0 to 23.0		3) 20427/20428	See WTB-31 Log (Elev = 7.1) Field Analysis - 21.0-23.0 pH = 4.3 - NO_3 = 0 Chemet Analysis - NH_3 - 1.908 / NO_3 - <0.02								
23.0 24.0				See WTB-31 Log								

BORING TERMINATED AT 34.0 FT BLS. LOGGED BY: C. Keith

COMMENTS:

☑ BORING
☐ EXCAVATION

FIELD LITHOLOGIC LOG

SITE NAME AND LOCATION Waste Treatment / next to WTB-31 4' N	PROJECT NO. 6498-019	BORING / EXCAVATION NO. WTB-35
DRILLING CONTRACTOR Skipper Well Drilling	DRILLING METHOD Geoprobe Direct Push	SHEET 4 OF 5
DRILLER R. Skipper	SAMPLING METHOD Probe / Peristaltic	DRILLING START TIME 10:50 / FINISH TIME 14:50
DRILLER S. Parrish		
GEOLOGIST C. Keith	WEATHER Sunny - 70's - 80's	START DATE 6-23-99 / FINISH DATE 6-23-99
DRILL RIG Concord 9200	SURFACE CONDITIONS improved grade	
ANGLE Vert. BEARING —		
DATUM Land Surface ELEVATION 30.10 Based on WTB-31	COORDINATES C. 5910.0 N / 13,268 E Based on WTB-31	

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
24.0 – 27.0 (24.0, 25.0, 26.0, 27.0)	25.0	27.0	4) 20929/20930	See WTB-31 Log (Elev = 3.1) Field Analysis - 25.0-27.0 pH = 3.9 / NO_3 = >500 NO_2 = (+) Chemet Analysis NH_3 = 206.547 / NO_3 = 1380								
27.0 – 30.0 (28.0, 29.0, 30.0)	28.0	30.0	5) 20931/20932	See WTB-31 Log (Elev. = 0.10) Field Analysis - 28.0-30.0 pH = 3.9 / NO_3 = >500 NO_2 = (+) Chemet Analysis NH_3 = 163.533 / NO_3 = 1170								
30.0 – 32.0 (31.0, 32.0)				See WTB-31 Log								

BORING TERMINATED AT 34.0 FT BLS. LOGGED BY: C. Keith

COMMENTS:

☑ BORING
☐ EXCAVATION

FIELD LITHOLOGIC LOG

SITE NAME AND LOCATION Waste Treatment / next to WTB-31 4' N	PROJECT NO. 6448-019	BORING / EXCAVATION NO. WTB-35
DRILLING CONTRACTOR Skipper Well Drilling	DRILLING METHOD Geoprobe Direct Push	SHEET 5 OF 5
DRILLER R. Skipper	SAMPLING METHOD Probe / Peristaltic	DRILLING START TIME 10:50 / FINISH TIME 14:50
DRILLER S. Parrish		
GEOLOGIST C. Keith	WEATHER Sunny - 70's - 80's	DATE 6-23-99 / DATE 6-23-99
DRILL RIG Concord 9200	SURFACE CONDITIONS improved grade	
ANGLE Vert. — BEARING —		
DATUM Land Surface — ELEVATION 30.10 Based on WTB-31	COORDINATES 0.6810.0N / 13,268E	Based on WTB-31

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
32.0				See WTB-31 Log (Elev = (-) 3.9 msl)								
33.0	32.0 to 34.0		⑥ 20433/20934	Field Analysis 32.0-34.0 pH = 6.21 / NO_3 = 7500 NO_2 = (+) CHemist Analysis NH_3 = 108.226 / NO_3 = 954								Top of Sandstone at 33.5' BLS (-) 3.4 Elev
34.0												

BORING TERMINATED AT 39.0 FT BLS. LOGGED BY: C. Keith

COMMENTS:

☑ BORING
☐ EXCAVATION

FIELD LITHOLOGIC LOG

SITE NAME AND LOCATION Waste Treatment / South ! East of Dam		PROJECT NO. 6448-019	BORING / EXCAVATION NO. WTB-36	
DRILLING CONTRACTOR Skipper Well Drilling		DRILLING METHOD Geoprobe Direct Push	SHEET 1 OF 4	
DRILLER R. Skipper			DRILLING	
		SAMPLING METHOD Probe / Peristaltic	START	FINISH
DRILLER S. Parrish			TIME 08:30	TIME 11:32
GEOLOGIST C. Keith / J. Rabon		WEATHER overcast - 80's	DATE 6-17-99	DATE 6-17-99
DRILL RIG Concord 9200		SURFACE CONDITIONS improved grade		
ANGLE Vert	BEARING —			
DATUM Land Surface	ELEVATION Based on 28.90 WTP-7	COORDINATES c. 6' South of N 5988 / E12959		

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
0.0												
1.0												
2.0												
3.0				Hammered Through to assumed top of clay @ 10.0' BLS Based on WTP-7								
4.0												
5.0												
6.0												
7.0												
8.0												

BORING TERMINATED AT 30.0 FT BLS. LOGGED BY: C. Keith

COMMENTS:

☑ BORING
☐ EXCAVATION

FIELD LITHOLOGIC LOG

SITE NAME AND LOCATION Waste Treatment/ South & East of Dam	PROJECT NO. 6448-019	BORING / EXCAVATION NO. WTB-36
DRILLING CONTRACTOR Skipper Well Drilling	DRILLING METHOD Geoprobe Direct Push	SHEET 2 OF 4
DRILLER R. Skipper	SAMPLING METHOD Probe/Peristaltic	DRILLING START TIME 08:30 / FINISH TIME 11:32
DRILLER S. Parrish	WEATHER overcast - 80's	START DATE 6-17-99 / FINISH DATE 6-17-99
GEOLOGIST C. Keith / J. Rabon	SURFACE CONDITIONS improved grade	
DRILL RIG Concord 9200		
ANGLE Vert. — BEARING —		
DATUM Land Surface — ELEVATION 28.80 Based on WTP-7	COORDINATES N5485/E 12959 - C. 6' south of	

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
8.0												
9.0												
10.0												
11.0				Top of Clay Elev - 16.80								
12.0												
13.0												
14.0												
15.0	14.0	16.0	Soil	Refusal on soil sample		0%						
16.0												

BORING TERMINATED AT 30.0 FT BLS.
LOGGED BY: C. Keith
COMMENTS:

☑ BORING
☐ EXCAVATION

FIELD LITHOLOGIC LOG

SITE NAME AND LOCATION Waste Treatment / South & East of Dam	PROJECT NO. 6448-019	BORING / EXCAVATION NO. WTB-36
DRILLING CONTRACTOR Skipper Well Drilling	DRILLING METHOD Geoprobe Direct Push	SHEET 3 OF 4
DRILLER R. Skipper	SAMPLING METHOD Probe / Peristaltic	DRILLING START TIME 08:30
DRILLER S. Parrish		DRILLING FINISH TIME 11:32
GEOLOGIST C. Keith / J. Rabon	WEATHER overcast - 80's	START DATE 6-17-99 FINISH DATE 6-17-99
DRILL RIG Concord 9200	SURFACE CONDITIONS improved grade	
ANGLE Vert.	BEARING —	
DATUM Land Surface	ELEVATION 28.80 Based on WTP-7	COORDINATES N5985/E12959 - c. 6' south of

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
16.0	16.0	18.0	So. 1	16.0-18.0 - Stiff Gray Clay with wood particles Elev - 12.8 - 10.8 msl		100%						Bottom ~~Top~~ of Clay Elev. 12.8 msl
17.0												
18.0	18.0	20.0	So. 1	18.0-18.5 - Moist Loose VF Sandy Clay 18.5-19.2 - Slightly organic Blackish grey Sandy clay 19.2-19.5 - Green Glauconitic Clayey Sand		75%						
19.0												
20.0	20.0	22.0	So. 1	20.0-20.8 - Green glauconitic VF sand/silt		40%						
21.0												
22.0												
23.0												
24.0												

BORING TERMINATED AT 80.0 FT BLS.   LOGGED BY: C. Keith

COMMENTS:

☐ EXCAVATION

FIELD LITHOLOGIC LOG

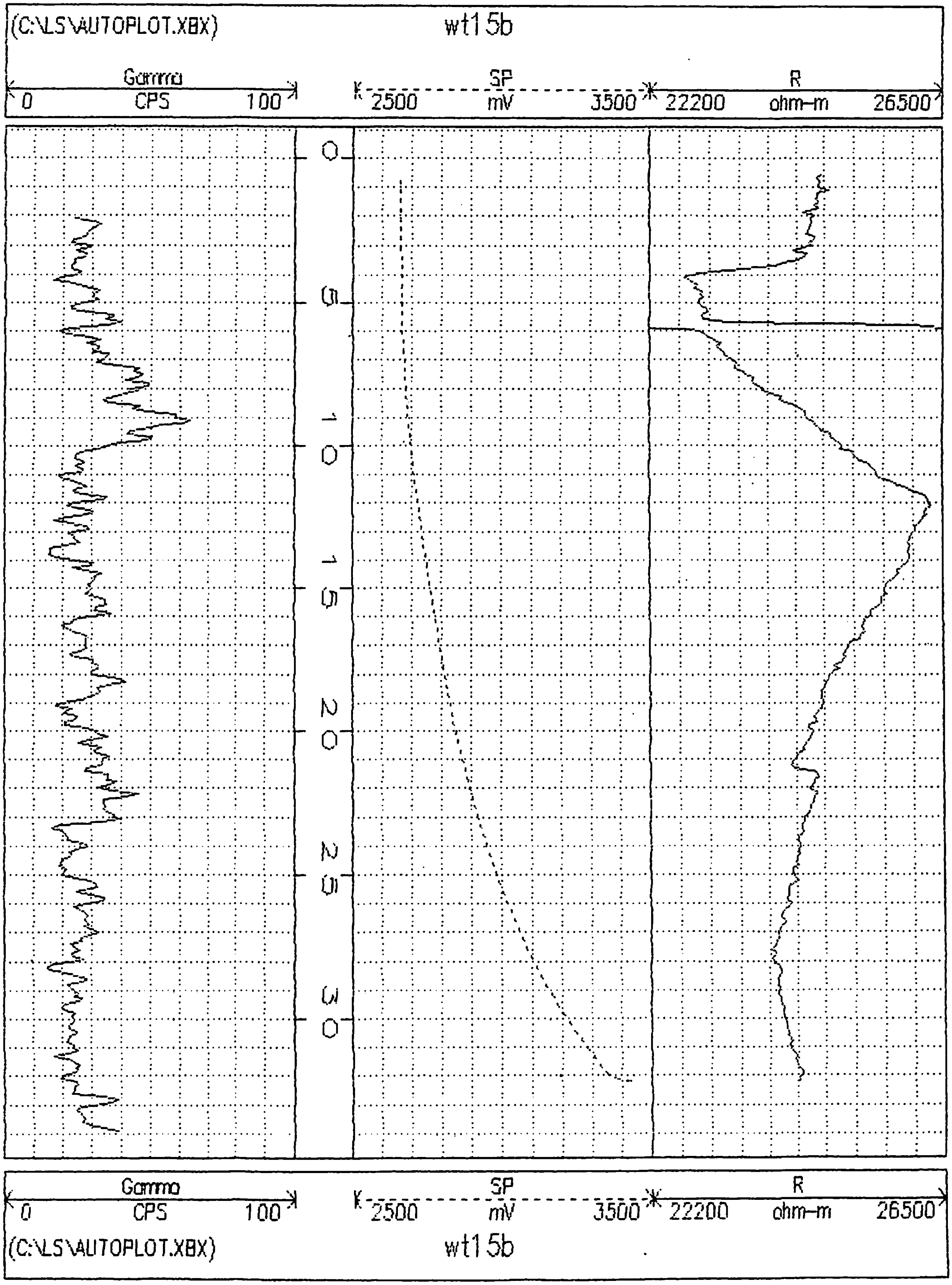
SITE NAME AND LOCATION Waste Treatment/ South & East of Dam	PROJECT NO. 6498-019	BORING / EXCAVATION NO. WTB-36
DRILLING CONTRACTOR Skipper Well Drilling	DRILLING METHOD Geoprobe Direct Push	SHEET 4 OF 4
DRILLER R. Skipper	SAMPLING METHOD Probe/Peristaltic	DRILLING START TIME 08:30 FINISH TIME 11:32
DRILLER S. Parrish		
GEOLOGIST C. Keith / T. Rabon	WEATHER overcast - 80's	START DATE 6-17-98 FINISH DATE 6-17-98
DRILL RIG Concord 9200	SURFACE CONDITIONS improved grade	
ANGLE Vert.	BEARING —	
DATUM Land Surface	ELEVATION 28.80 Based on WTP-7	COORDINATES N 5985/E 12959 – c. 6' south of

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
24.0	23.0 to 25.0		(2) 20943 20944	Field Analysis – pH – 6.8 NO_3 = 0 – Conductivity – 101.9 Chemet Analysis – NO_3 = <0.2 NH_3 = 0.587 (Elev – 3.8 msl)								
25												
26.0												
27.0												
28.0	28.0 to 30.0		(2) 20945/20946	Field Analysis – pH = 6.41 Conductivity = 169.5 NO_3 = 50 Chemet Analysis NH_3 = 0.403 ppm NO_3 = 18.0 Elev – (–) 1.20								
29.0												Top of Sandstone 30.0 Elev. = (–) 1.20 MSL
30.0												

BORING TERMINATED AT 30.0 FT BLS.

LOGGED BY: C. Keith

COMMENTS: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wt15b
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CPS
100
SP
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3500
R
22200
ohm-m
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Gamma
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22200
ohm-m
26500
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wt15b

SITE NAME AND LOCATION Waste Treatment / C. 100' South & East of WTB-32	**PROJECT NO.** 6448-019	**BORING / EXCAVATION NO.** WTB-37
DRILLING CONTRACTOR Skipper Well Drilling	**DRILLING METHOD** Geoprobe Direct Push	**SHEET** 1 of 2
DRILLER R. Skipper	**SAMPLING METHOD** Probe / Peristaltic	**DRILLING** **START** TIME 13:40 / **FINISH** TIME 16:00
DRILLER S. Parrish		
GEOLOGIST C. Keith / S. O'Brien	**WEATHER** overcast - 80's	**DATE** 6-16-99 / **DATE** 6-16-99
DRILL RIG Concord 9200	**SURFACE CONDITIONS** improved grade	
ANGLE Vert	**BEARING** —	
DATUM Land Surface	**ELEVATION** C. 27.69 Based on WTB-32	**COORDINATES** C. N 5880 / E 13018

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
0.0												
1.0												
2.0				See WTB-32 Hammered to 9.0' BLS assuming top of clay based on WTB-32 Log								
3.0												
4.0												
5.0												
6.0												
7.0												
8.0												

BORING TERMINATED AT 12.0 FT BLS. LOGGED BY: C. Keith

COMMENTS:

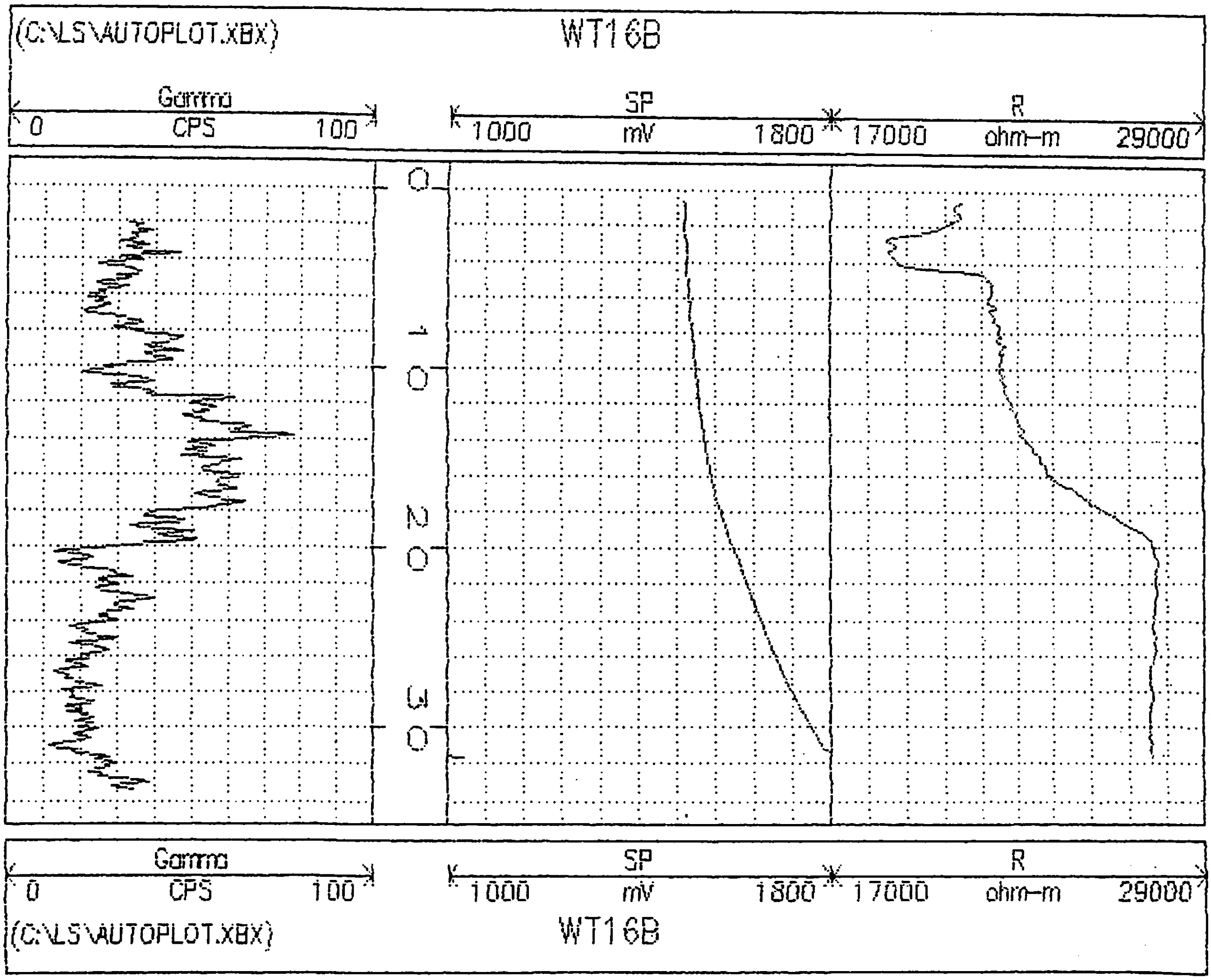
SITE NAME AND LOCATION Waste Treatment / c.100' south & East of WTB-32	PROJECT NO. 6448-019	BORING / EXCAVATION NO. WTB-37
DRILLING CONTRACTOR Skipper Well Drilling	DRILLING METHOD Geoprobe Direct Push	SHEET 2 OF 2
DRILLER R. Skipper	SAMPLING METHOD probe/peristaltic	DRILLING START TIME 13:40 / FINISH TIME 16:00
DRILLER S. Parrish		
GEOLOGIST C. Keith / S. O'Brien	WEATHER overcast - 80's	DATE 6-16-99 / DATE 6-16-99
DRILL RIG Concord 9200	SURFACE CONDITIONS improved grade	
ANGLE Vert	BEARING —	
DATUM Land Surface	ELEVATION Based on WTB-32 c. 27.69	COORDINATES c. N5884 / E13018

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
8.0	7.0	9.0	1) Field	Field Analysis - 7.0-9.0 NO_x = 0 (Elev. = 18.69)								
9.0				See WTB-32								
10.0				10.0 - 10.9 - Stiff green glauconitic clay (Elev. = 17.69 msl)	∼ ∼							
11.0				10.8 - 11.5 5' down VF Dry white compacted sand with coarse to pebble size ~~Angular weathered grains~~ Acrid odor (Elev = 16.19 msl)	∴	75%						Sharp transition from clay to sand
12.0												Refusal Note: 5 Boreholes hammered in area to refusal

BORING TERMINATED AT 12.0 FT BLS.

LOGGED BY: C. Keith

COMMENTS: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CPS
100
SP
1000
mV
1800
R
17000
ohm-m
29000
0
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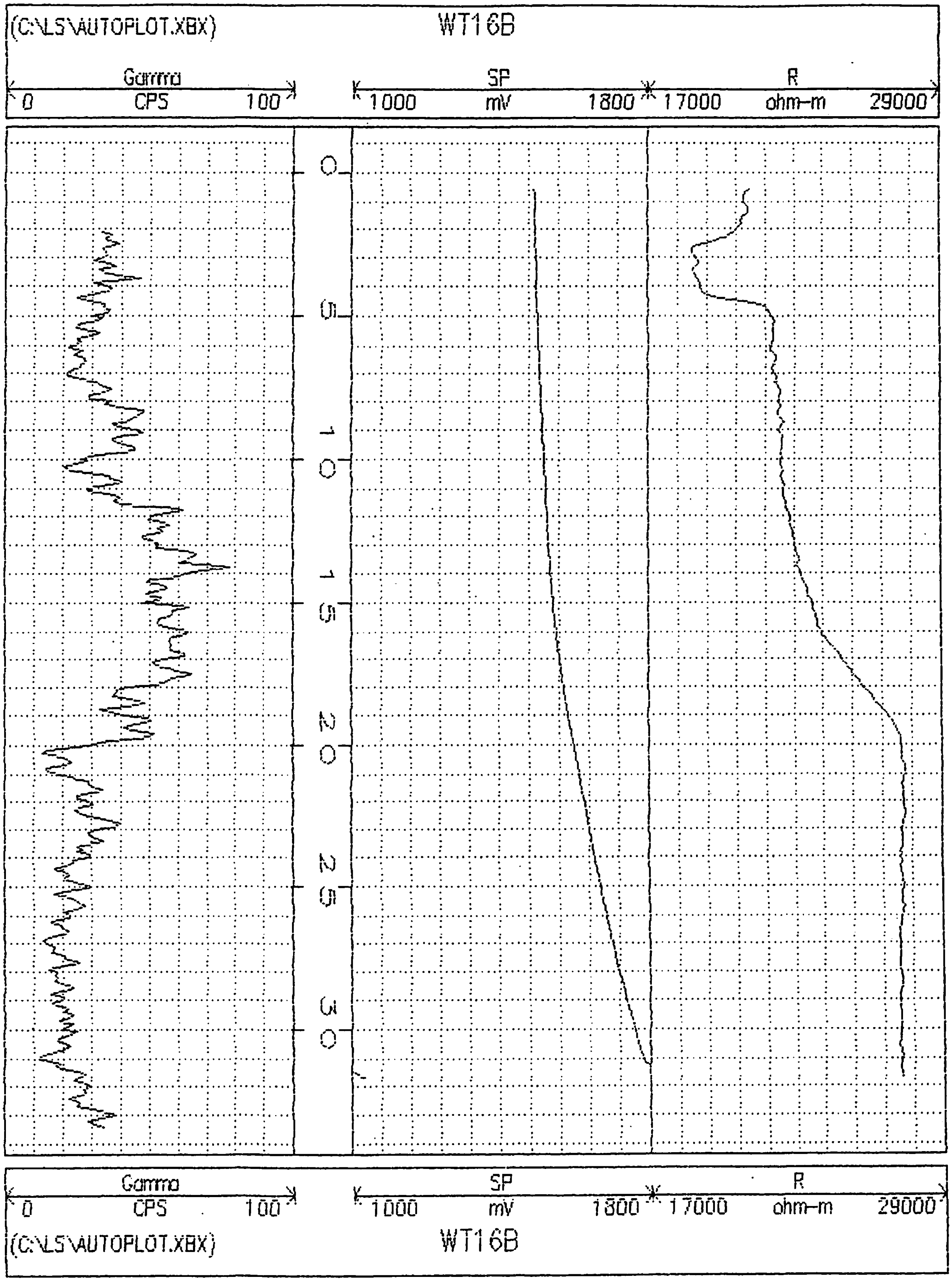
WT16B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WT16B
Gamma
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CPS
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SP
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mV
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17000
ohm-m
29000
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Gamma
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29000
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WT16B

☐ EXCAVATION

SITE NAME AND LOCATION South of Spoil Waste Treatment/ East of Coord.	PROJECT NO. 6448-019	BORING / EXCAVATION NO. WTB-38	
DRILLING CONTRACTOR Skipper Well Drilling	DRILLING METHOD Geoprobe Direct Push	SHEET 1 OF 5	
DRILLER R. Skipper		DRILLING	
	SAMPLING METHOD	START	FINISH
DRILLER S. Parrish	Probe/ Peristaltic	TIME 09.30	TIME 10:~~47~~ 54
GEOLOGIST C. Keith / S. O'Brien	WEATHER overcast to rain - 70's-80's	DATE 6-15-99	DATE 6-16-99
DRILL RIG Concord 9200	SURFACE CONDITIONS graded		
ANGLE Vert	BEARING —		
DATUM Land Surface	ELEVATION Based on 28.59 WTP-8	COORDINATES c. 10' South of N5567/E13458 ; 5' East of	

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
0.0												
1.0												
2.0												
3.0				Hammered through to projected top of Clay Based on WTP-8								
4.0												
5.0												
6.0												
7.0												
8.0												

BORING TERMINATED AT 36.2 FT BLS. LOGGED BY: C. Keith

COMMENTS:

☐ EXCAVATION

FIELD LITHOLOGIC LOG

SITE NAME AND LOCATION Waste Treatment/ South of Spoil & East of Coord.	PROJECT NO. 6448-019	BORING / EXCAVATION NO. WTB-38
DRILLING CONTRACTOR Skipper Well Drilling	DRILLING METHOD Geoprobe Direct Push	SHEET 2 OF 5
DRILLER R. Skipper	SAMPLING METHOD Probe / Peristaltic	DRILLING START TIME 08:30 FINISH TIME 10:54
DRILLER S. Parrish		
GEOLOGIST C. Keith / S. O'Brien	WEATHER overcast to rain - 70's-80's	START DATE 6-15-99 FINISH DATE 6-16-99
DRILL RIG Concord 9200	SURFACE CONDITIONS graded	
ANGLE Vert.	BEARING —	
DATUM Land Surface	ELEVATION 28.59 Based on WTP-8	COORDINATES N5567/E13458 c. 10' South of & 5' East of

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
8.0												
9.0												
10.0	10.0	12.0	So.1	10.0-11.1 Fine to VF Light Brownish Red Sand 11.1-11.4-F-VF orange oxidized to Brownish Red to Black organic sand 11.4-11.6 - Dark Brownish Black Clay		80%						
11.0												
12.0	12.0	14.0	So.1	12.0 - 12.7 - Greenish Gray Sandy Clay		35%						Top of Clay Elev -16.59 msl
13.0												
14.0	14.0	16.0	So.1	14.0 - 15.7 - Very Stiff Greenish Gray Clay		85%						
15.0												
16.0												

BORING TERMINATED AT 36.2 FT BLS. LOGGED BY: C. Keith

COMMENTS:

☑ BORING
☐ EXCAVATION

FIELD LITHOLOGIC LOG

SITE NAME AND LOCATION Waste Treatment/ South of Spoil : East of Coord.	PROJECT NO. 6448-019	BORING / EXCAVATION NO. WTB-38
DRILLING CONTRACTOR Skipper Well Drilling	DRILLING METHOD Geoprobe Direct Push	SHEET 3 OF 5
DRILLER R. Skipper	SAMPLING METHOD Probe / Peristaltic	DRILLING START TIME 08:30 / FINISH TIME 10:54
DRILLER S. Parrish		
GEOLOGIST C. Keith / S. O'Brien	WEATHER overcast to rain - 70's-80's	START DATE 6-15-99 / FINISH DATE 6-16-99
DRILL RIG Concord 9200	SURFACE CONDITIONS graded	
ANGLE Vert	BEARING —	
DATUM Land Surface	ELEVATION 28.59 Based on WTP-8	COORDINATES N 5567 / E 13458 c. 10' South of : 5' East of

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
16.0	16.0	18.0	Soil	16.0 - 17.9 - Gradational slightly sandy med grey clay into stiff med grey down to stiff dark grey clay		95%						
17.0												
18.0	18.0	20.0	Soil	18.0 - 19.0 - Saturated VF grey sandy clay		100%						
19.0				19.0 - 20.0 - Gradational med ~~grey~~ down to dark grey stiff clay								
20.0	20.0	22.0	Soil	20.0 - 21.1 - Dark grey sand/clay		55%						
21.0												Bottom of Clay Elev = 6.59 msl
22.0												Rained out
23.0												
24.0												

BORING TERMINATED AT 36.2 FT BLS. LOGGED BY: C. Keith

COMMENTS:

☑ BORING
☐ EXCAVATION

FIELD LITHOLOGIC LOG

SITE NAME AND LOCATION Waste Treatment / South of Spoil & East of Conrd	PROJECT NO. 6448-019	BORING / EXCAVATION NO. WTB-38
DRILLING CONTRACTOR Skipper Well Drilling	DRILLING METHOD Geoprobe Direct Push	SHEET 2 of 5
DRILLER R. Skipper	SAMPLING METHOD Probe / Peristaltic	DRILLING START TIME 08:30 / FINISH TIME 10:54
DRILLER S. Parrish		
GEOLOGIST C. Keith / S. O'Brien	WEATHER overcast to rain - 70's-80's	START DATE 6-15-99 / FINISH DATE 6-16-99
DRILL RIG Concord 9200	SURFACE CONDITIONS graded	
ANGLE Vert. / BEARING —		
DATUM Land Surface / ELEVATION 28.59 Based on WTP-8	COORDINATES N5567 / E13458 c. 10' South of & 5' East of	

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
24.0	23.0	25.0	1) 204P0 204P1	Elev - 3.59 msl Field Analysis - pH = 4.9 - NO_3 = 0 Conductivity = 160.6 Chemist Analysis - NH_3 = 1.340 ppm / NO_3 = <0.2								Abandoned previous Borehole due to rain. water in Boring moved 4' south to hammer through clay
26.0												
26.0												
27.0	28.0	30.0	2) 204P2 / 204P3	Elev - (-) 1.41 Field Analysis - pH = 6.0 - NO_3 - 0 Conductivity = 285.5 Chemist Analysis NH_3 = 0.403 / NO_3 = <0.2								
28.0												
29.0												
30.0												
31.0												
32.0												

BORING TERMINATED AT 36.2 FT BLS.   LOGGED BY: C. Keith

COMMENTS:

☑ BORING
☐ EXCAVATION

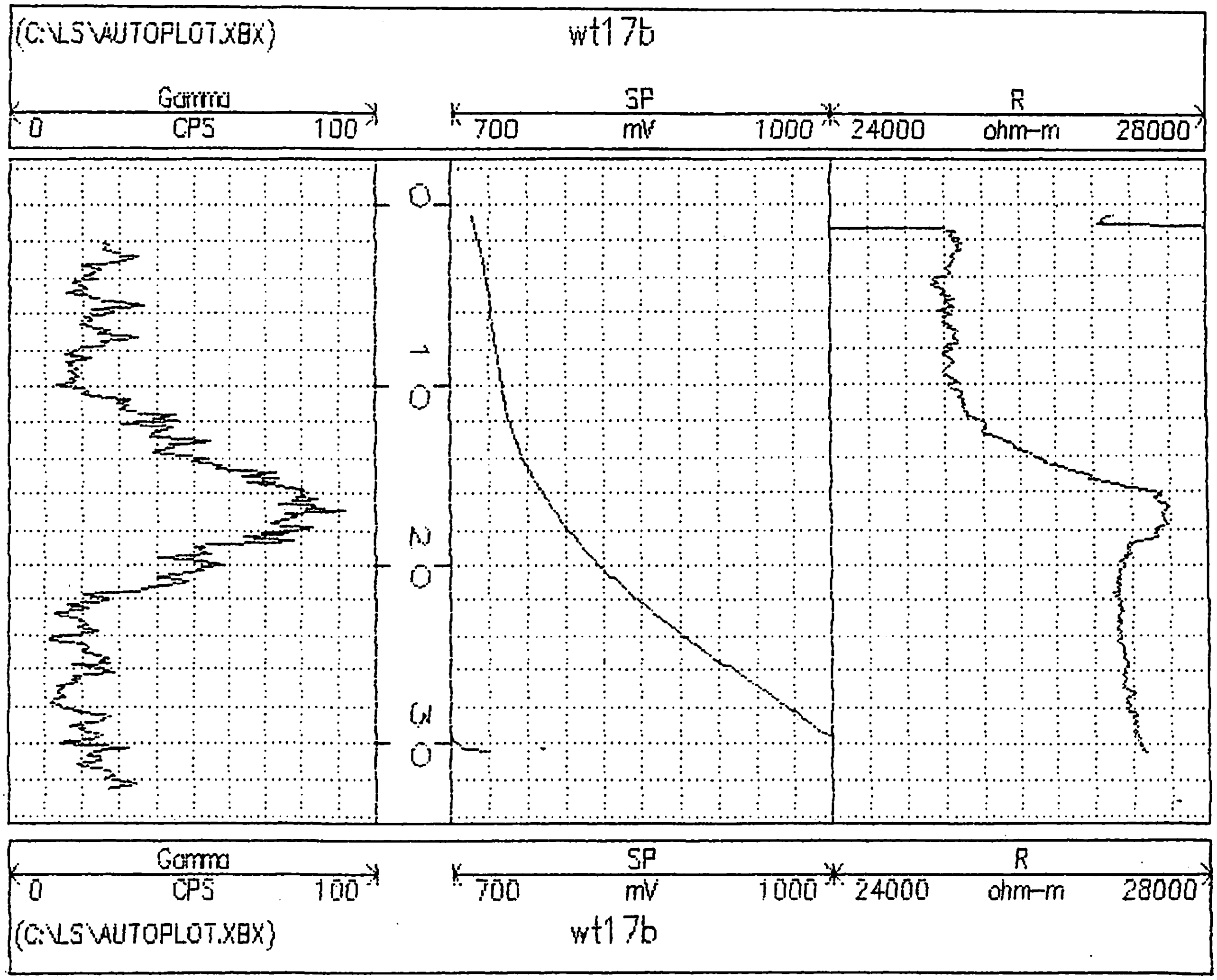
FIELD LITHOLOGIC LOG

SITE NAME AND LOCATION Waste Treatment / South of Spoil & East Coord.	PROJECT NO. 6448-019	BORING / EXCAVATION NO. WTB-38
DRILLING CONTRACTOR Skipper Well Drilling	DRILLING METHOD Geoprobe Direct Push	SHEET 5 OF 5
DRILLER R. Skipper	SAMPLING METHOD Probe / Peristaltic	DRILLING START TIME 08.30 FINISH TIME 10:54
DRILLER S. Parrish		
GEOLOGIST C. Keith / S. O'Brien	WEATHER Overcast to Rain - 70's-80's	DATE 6-15-99 DATE 6-16-99
DRILL RIG Concord 9200	SURFACE CONDITIONS Graded	
ANGLE Vert.	BEARING —	
DATUM Land Surface	ELEVATION 28.59 Based on WTP-8	COORDINATES N 5567 / E 13458 c. 10' South of & 5' East of

DEPTH IN FEET (ELEVATION)	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	SAMPLE NO.	DESCRIPTION OF MATERIAL	LOG	% RECOVERY	CASING	SPT (BLOWS)	RESISTANCE	WATER LEVEL LOCATION	WATER LEVEL TIME/DATE	REMARKS
32.0												
33.0 34.0	33.0	35.0	3) 204P4 / 204P5	Elev - (-) 6.41 Field Analysis - pH = 6.3 / Nitrate = 0 Conductivity = 272.4 Chemet Analysis NH_3 = 0.418 / NO_3 = 0.255								
35.0 36.0		36.2	4) 204P6 204P7	El~~ev~~= (-) 7.61 Field Analysis - pH = 6.9 NO_3 = 0 - Conductivity = 324.2 Chemet Analysis NH_3 = <0.4 / NO_3 = 0.280								Top of Sandstone 36.2' BLS Elev. (-) 7.61
37.0												

BORING TERMINATED AT 36.2 FT BLS. LOGGED BY: C. Keith

COMMENTS: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CPS
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ohm-m
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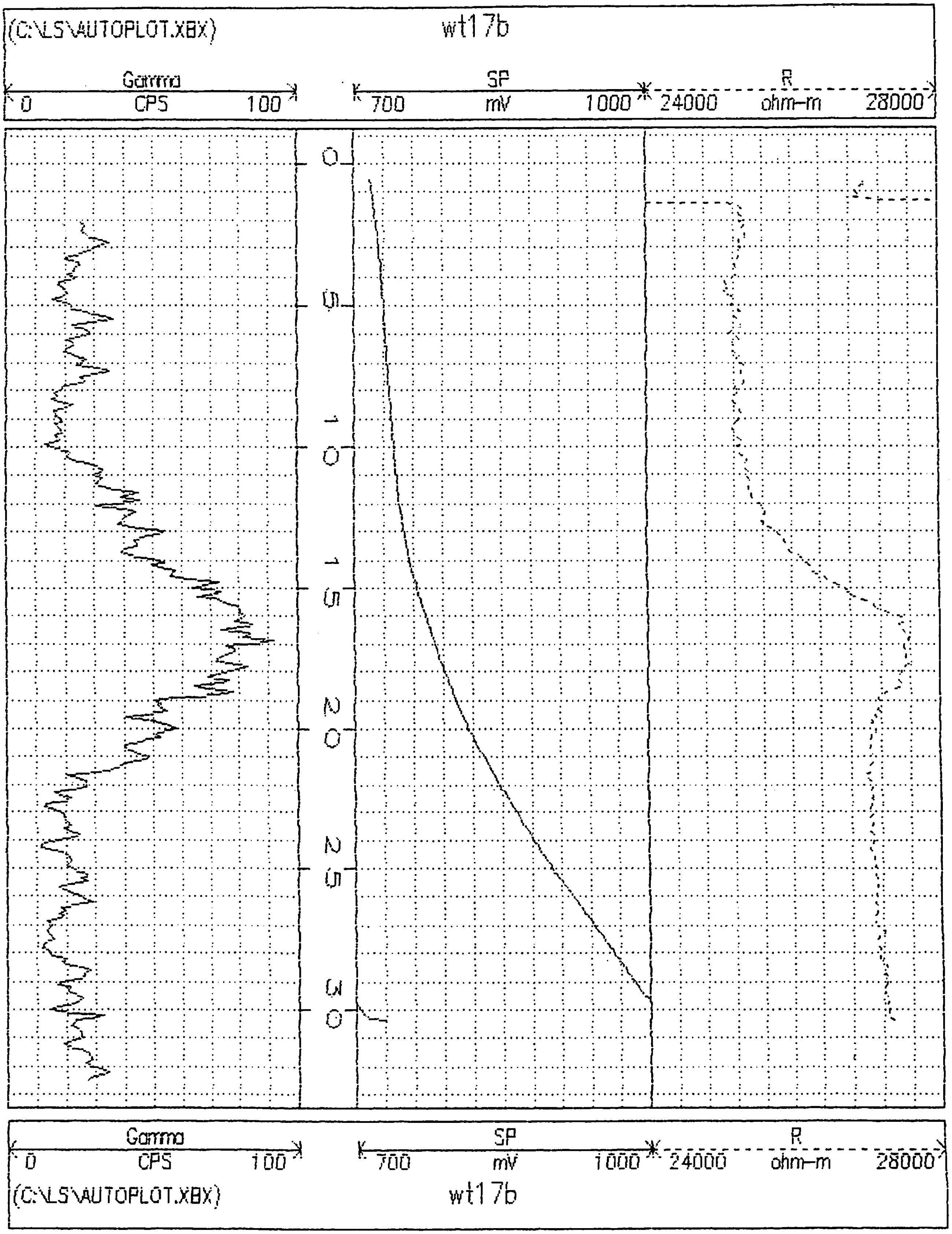
wt17b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wt17b
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ohm-m
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(C:\LS\AUTOPLOT.XBX)
wt17b

Historical WT Area Lithologic Logs

Borings/Monitoring Wells

Logging Performed by Research Triangle Institute

Boring	Well Numbers*
Area 1 Boring	CW-1A, CW-1B, CW-1C
Area 2 Boring	CW-2A, CW-2B
Area 3 Boring	CW-3A, CW-3B
Area 4 Boring	CW-4B, CW-4C
Area 5 Boring	CW-5B
Area 6 Boring	CW-6A, CW-6B

* see Figure 1-2 for well location

EXPLORATORY SOIL BORING: AREA 1
(WELLS CW-1A, CW-1B, CW-1C)

Date Drilled: October 24, 1989
Plant Coordinates: N4840; E14,200
Approximate Ground Elevation: 28.0

RTI Project No. 4419-006

Recovered Sample Depth Below Ground Surface	Lithologic Description	Penetration Resistance (18-inch samples)	Sample Recovery (Percent)
	***Surficial Aquifer* (0 - 10.7 ft.)**	N-VALUE	
0 - 1.5	Black, silty, organic rich, medium, well-sorted sand.	1-1-1 (2)	67
1.5 - 1.8	Black-gray, silty, fine sandy, soft clay.	1-2-1 (3)	100
2.2 - 2.3	Gray, silty, soft clay.		
2.3 - 3.0	Black to dark brown, very silty, well-sorted, medium to fine sand.		
3.0 - 3.5	Black to dark brown, silty, fairly well sorted, medium to fine sand.	1-2-2 (4)	3
4.5 - 5.3	Gray, silty, poorly sorted, medium to coarse sand.	1-2-2 (4)	85
5.3 - 5.7	Wood.		
6.0 - 6.85	Mottled gray and brown, silty, fairly well sorted, medium to coarse sand.	2-4-4 (8)	57

Recovered Sample Depth Below Ground Surface	Lithologic Description	Penetration Resistance (18-inch samples)	Sample Recovery (Percent)
7.5 - 7.65	Gray, silty, well-sorted, fine sandy, soft clay.	4-7-9 (16)	74
7.65 - 8.6	Gray, silty, fine sand.		
9.0 - 10.1	Mottled gray and brown, silty and slightly clayey, poorly sorted medium to fine sand.	1-3-6 (9)	74
	***Semiconfining Unit** (10.5 - 17.0 ft.)*		
10.5 - 10.75	Gray, silty, medium to fine, sandy, soft clay.	4-5-16 (21)	74
10.75 - 11.15	Gray, slightly fine, sandy clay with wood inclusion.		
11.15 - 11.5	Gray, clayey, fine to medium sand.		
12.0 - 12.6	Gray, glauconitic, silty, well-sorted medium sand with some well-rounded, fine-grained quartz gravel.	11-11-4 (15)	40
13.5 - 14.25	Light green, glauconitic, well-sorted, fine sandy, dense clay.	1-1-1 (2)	50
15.0 - 16.5	Green, glauconitic, fine to medium very sandy, soft clay with a thin laminae of fine to very coarse gravel at 15.9 feet and rootlets.	1-1-1 (2)	100
16.5 - 17.0	Gray and green, glauconitic, fine to medium very sandy, soft clay, with rootlets.	2-3-5 (8)	73

Recovered Sample Depth Below Ground Surface	Lithologic Description	Penetration Resistance (18-inch samples)	Sample Recovery (Percent)
	Principal Aquifer (Peedee Formation) ***(17.0 - 64.5 feet)***		
17.0 - 17.6	Green, glauconitic, silty, well-sorted, medium sand with rootlets. Nitrate not detected.	2-3-7 (10)	47
18.0 - 18.7	Green, silty, glauconitic, well-sorted, fine to medium sand. Nitrate not detected.	6-8-7 (15)	45
19.5 - 21.0	Green, silty, glauconitic, well-sorted, fine to medium sand.		
21.0 - 21.6	Green, silty, glauconitic, well-sorted, medium sand.	6-7-16 (23)	45
22.5 - 22.95	Light green and gray, silty, glauconitic, well-sorted, fine to medium sand.	12-23-25 (48)	74
22.95 - 23.65	Tan, silty, glauconitic, well-sorted, fine to medium sand.		
24.0 - 24.9	Light brown, silty, glauconitic, well-sorted, very fine to fine sand. Nitrate not detected.	12-19-11 (30)	100
25.5 - 27.0	Light brown, silty, glauconitic, well-sorted, very fine to fine sand.	6-12-13 (25)	100
27.0 - 28.0	Light brown, silty, glauconitic, well-sorted, very fine to fine sand. Nitrate not detected.	5-6-9 (15)	67
28.5 - 28.59	Light brown, silty, glauconitic well-sorted, very fine to fine sand.	4-7-9 (16)	6

Recovered Sample Depth Below Ground Surface	Lithologic Description	Penetration Resistance (18-inch samples)	Sample Recovery (Percent)
30.0 - 30.09	Light brown, silty, glauconitic, well-sorted, very fine to fine sand.	7-7-8 (15)	6
31.5 - 32.2	Gray and green, very silty, glauconitic, well-sorted, very fine sand.	3-3-7 (10)	47
33.0 - 33.6	Gray and green, very silty, glauconitic, well-sorted, very fine sand. Nitrate not detected.	6-6-9 (15)	47
34.5 - 35.1	Gray and green, very silty, glauconitic, well-sorted, very fine sand.	3-3-5 (8)	47
36.0 - 36.9	Gray and green, very silty, glauconitic, well-sorted, very fine sand.	8-13-14 (27)	60
37.5 - 38.4	Green, silty, glauconitic, well-sorted, very fine to fine sand with green well-sorted, fine to very fine grained sandstone and medium to coarse gravel with shell fragments.	19-23-35 (58)	60
39.0 - 39.7	Green, silty, glauconitic, well-sorted very fine to fine, sand with some shell fragments.	21+50/6" (100)	60
40.5 - 40.9	Green, silty, glauconitic, fairly well sorted, very fine to fine sand, with some coarse quartz gravel and a thin layer of sandstone. Nitrate not detected.	34/6" (34) 50/6" (100)	27

Recovered Sample Depth Below Ground Surface	Lithologic Description	Penetration Resistance (18-inch samples)	Sample Recovery (Percent)
42.0 - 42.6	Green, silty, glauconitic, fairly well sorted, very fine to fine sand, with some coarse quartz gravel and a thin layer of sandstone.	26-33-35(68)	40
43.5 - 45.0	No recovery.	23-30-31 (61)	
45.0 - 45.5	Thin layer of dark green, glauconitic, fine, sandy clay overlying green, very silty, glauconitic, fairly well-sorted, very fine to fine sand.	17-35-55 (90)	33
46.5 - 47.2	Green, silty, glauconitic, fairly well sorted, very fine to fine sand with some shell fragments.	15-32-54 (86)←	47
48.0 - 48.7	Green, silty, glauconitic, fairly well sorted, very fine to fine sand with some shell fragments.	25-33-40(73)	47
49.5 - 50.2	Green, silty, glauconitic, fairly well sorted, very fine to fine sand with some shell fragments.	23-31-32 (63)	47
51.0 - 51.7	Green, silty, glauconitic, fairly well sorted, very fine to fine sand with some shell fragments. Thin layer of well-sorted, fine-grained fossiliferous sandstone (0.5 ft. thick).	23-34-33 (67)	33
52.5 - 53.2	Green, silty, glauconitic, fairly well sorted, very fine to fine sand with some shell fragments.	16-28-33 (61)	47

Recovered Sample Depth Below Ground Surface	Lithologic Description	Penetration Resistance (18-inch samples)	Sample Recovery (Percent)
54.0 - 54.8	Green, silty, glauconitic, well-sorted, very fine to fine <u>sand</u>.	17-28-33 (61)	48
55.5 -56.25	Green, silty, glauconitic, well-sorted, very fine to fine <u>sand</u>.	28-42-50 (92)	50
57.0 - 57.85	Green, silty, glauconitic, well-sorted, very fine to fine <u>sand</u> with a thin layer (0.05 ft.) of green, well-sorted, fine-grained glauconitic, fossiliferous <u>sandstone</u>.	18-32-47 (79)	57
58.5 - 59.0	Green, silty, glauconitic, well-sorted, very fine to fine <u>sand</u>.	24-40-50/5" (~~50~~ 100)	33
60.0 - 60.8	Green, silty, glauconitic, well-sorted, very fine to fine <u>sand</u>.	16-31-40 (71)	53
61.5 - 61.9	Green, silty, glauconitic, well-sorted, very fine to fine <u>sand</u>, with a thin layer of <u>sandstone</u>.	35-50/3" (100)	27
63.0 - 64.5	Gray-green, very silty, glauconitic, poorly sorted, very fine <u>sand</u>. Nitrate not detected.	8-11-16 (27)	100
64.5 - 66.0	Dark gray-green, glauconitic, poorly sorted, fine, very sandy <u>silt</u>. Nitrate not detected.	9-10-13 (23)	100
66.0 - 66.4	Dark gray-green, glauconitic, well-sorted, fine-grained <u>sandstone</u>. Nitrate not detected.	6-50/6" (100)	47
70.5 - 72.0	Dark gray-green, very fine, very sandy, poorly sorted, <u>silt</u>. Nitrate not detected.	8-8-15 (23)	100

Recovered Sample Depth Below Ground Surface	Lithologic Description	Penetration Resistance (18-inch samples)	Sample Recovery (Percent)
73.5 - 75.0	Dark gray-green, very fine, very sandy, poorly sorted, silt.	8-12-19 (31)	100
78.5 - 80.0	Dark gray-green, very fine, very sandy, poorly sorted, silt.	15-18-26 (44)	100
90.0	Dark gray-green, very fine, very sandy, poorly sorted, silt. Sample from bottom of bit.	(?)	

Boring Termination Depth: 90 feet below ground surface

Abandonment Procedure: 168 lbs. of Type I Portland Cement was mixed with approximately 20 gallons of water. The neat cement slurry was pumped through the drill stem from the borehole bottom up to the ground surface.

FROM 30' - B.T

Blows / 6"; $\bar{X}$ = 33.7 MAX: 100 N: $\bar{x}$=63.34 MIN: 8
SD = 19 MIN: 3 SD = 29 MAX: 100

EXPLORATORY SOIL BORING: AREA 2
(WELLS CW-2A, CW-2B)

Date Drilled: October 26, 1989
Plant Coordinates: N3910; E13,715
Approximate Ground Elevation: 40.0

RTI Project No. 4419-006

Recovered Sample Depth Below Ground Surface	Lithologic Description	Penetration Resistance (18-inch samples) N	Sample Recovery (Percent)
	Surficial Aquifer (0 - 21 ft.)		
0 - 0.16	Dark brown, medium sandy, organic-rich layer.	4-3-3 (6)	73
0.16 - 0.26	Brown, medium sand with a white leachate.		
0.26 - 0.36	Mottled black and gray, silty, medium sand.		
0.36 - 0.43	Brown, slightly silty, medium sand with rootlets.		
0.43 - 0.46	Peaty layer.		
0.46 - 1.1	Brown, slightly silty, medium sand with rootlets.		
1.5 - 3.0	Brown, slightly silty, well-sorted medium sand.	3-2-2 (4)	10
3.0 - 3.05	Black, silty, poorly sorted, medium sand with limestone gravel.	5-4-4 (8)	30
3.05 - 3.45	Tan, slightly silty, slightly clayey, fairly well sorted, medium sand.		
4.5 - 5.3	Mottled brown and tan, slightly silty, well-sorted, medium sand.	5-7-9 (16)	53

Recovered Sample Depth Below Ground Surface	Lithologic Description	Penetration Resistance (18-inch samples)	Sample Recovery (Percent)
6.0 - 7.0	Mottled brown and tan, slightly silty, well-sorted, medium sand.	6-11-12 (23)	67
7.5 - 8.4	Mottled brown and tan, slightly silty, well-sorted, medium sand.	5-12-15 (27)	60
9.4 - 9.7	Light brown-white, slightly silty, glauconitic, well-sorted, medium sand.	9-12-12 (24)	47
10.5 - 11.1	Mottled brown and tan, slightly silty, glauconitic, well-sorted medium sand.	6-9-11 (20	49
11.1 - 11.4	Light brown-white, slightly silty, medium sand.		
12.0 - 12.5	Light brown-white, slightly silty, poorly sorted, medium to coarse sand.	6-8-8 (16)	33
13.5 - 13.85	Mottled gray and tan, slightly silty, glauconitic, poorly sorted, fine to medium sand.	6-9-9 (18)	40
13.85 - 14.10	Mottled tan and white, silty, glauconitic, poorly sorted, medium to coarse sand.		
15.35 - 15.40	Gray, very clayey, fine to medium sand. Nitrate not detected.	5-5-2 (7)	40
16.5 - 18.0	Tan streaked with gray, silty and clayey, glauconitic, fairly well sorted, fine to medium sand. Nitrate not detected.	2-1-4 (5)	100
18.0 - 18.65	Mottled tan, pinkish brown, slightly silty, glauconitic, fairly well sorted, medium to fine sand. Nitrate detected.	6-7-7 (14)	43

Recovered Sample Depth Below Ground Surface	Lithologic Description	Penetration Resistance (18-inch samples)	Sample Recovery (Percent)
20.4 - 20.5	Gray and black, slightly clayey glauconitic, fairly well sorted, medium to coarse sand. Nitrate detected.	13-13-13 (26)	67
	***Semiconfining Unit** (21 - 27.5 ft.)*		
21.0 - 21.65	Gray, poorly sorted, coarse to very coarse sandy, dense clay. Nitrate not detected.	7-5-7 (12)	100
21.65 - 22.20	Gray, poorly sorted, very fine to fine sandy, dense clay.		
22.2 - 22.40	Gray, poorly sorted, medium to fine sandy, dense clay.		
22.5 - 23.15	Gray, glauconitic, very clayey, coarse sand with fine quartz gravel.	6-5-4 (9)	80
23.15 - 23.65	Gray, glauconitic, fine sandy, dense clay.		
24.0 - 25.3	Gray, glauconitic, fine sandy, dense clay.	2-3-3 (6)	100
25.3 - 25.5	Gray, glauconitic, coarse sandy, dense clay.		
25.5 - 25.8	Green and gray, glauconitic, coarse to very coarse sandy, soft clay.	2-2-3 (5)	100
25.8 - 26.0	Green and gray, glauconitic, medium to fine sandy, soft clay.		
26.0 - 26.15	Green and gray, glauconitic, very clayey, fairly well sorted, medium to coarse, sand.		
26.15 - 26.80	Green and gray, glauconitic, very fine sandy, soft clay.		
26.8 - 27.0	Green and gray, very clayey, well-sorted, fine sand.		

Recovered Sample Depth Below Ground Surface	Lithologic Description	Penetration Resistance (18-inch samples)	Sample Recovery (Percent)
27.0 - 27.5	Green and gray, glauconitic, silty, very fine sandy, dense clay.	2-1-1 (2)	100
	Principal Aquifer (Peedee Formation) *(27.5 - 69.5 feet)*		
27.5 - 28.5	Green and gray, glauconitic, clayey, well-sorted, very fine sand.	2-1-1 (2)	100
28.5 - 29.25	Green and gray, glauconitic, very silty, well-sorted, fine sand.	4-7-11 (18)	73
29.25 - 29.60	Tan to orange, silty, well-sorted, fine sand. Nitrate not detected.		
30.0 - 30.9	Greenish brown and tan, glauconitic, silty, well-sorted, fine sand. Nitrate not detected.	6-8-10 (18)	60
33.0 - 33.5	Greenish brown, glauconitic, silty, well-sorted, very fine sand.	11-28-38 (66)	33
36.0 - 37.0	Greenish brown, glauconitic, silty, well-sorted, very fine sand, with some fine quartz gravel.	12-34-34 (68)	67
40.5 - 41.4	Greenish brown, glauconitic, silty, well-sorted, very fine sand.	9-16-18 (34)	60
45.0 - 45.9	Greenish brown, glauconitic, silty, well-sorted, very fine sand.	24-23-30 (53)	100

Recovered Sample Depth Below Ground Surface	Lithologic Description	Penetration Resistance (18-inch samples)	Sample Recovery (Percent)
47.0 - 48.5	Greenish brown, glauconitic, silty, well-sorted, very fine sand, with a thin layer (0.01 ft.) of cemented brown sandstone at top. Sample is saturated.	20-40-43 (83)	100
50.0 - 50.8	Greenish brown, glauconitic, silty, poorly sorted, fine to very fine sand.	28-25-23 (48)	53
53.0	Thin sandstone layer. Determined by drilling resistance.		
54.0	Thin sandstone layer. Determined by drilling resistance.		
54.5 - 56.0	Green, silty, glauconitic, fairly well sorted, fine to very fine sand.	38-55/6 in. (93)	100
56.5	Thin sandstone layer. Determined by drilling resistance.		
58.5 - 59.3	Green, silty, glauconitic, well-sorted, fine sand.	38-35-39 (74)	67
59.3 - 59.35	Green, glauconitic, well-sorted fine-grained, fossiliferous sandstone.		
59.35 - 59.6	Green, silty, glauconitic, fine sand.		
59.6 - 59.7	Green, glauconitic, fine-grained sandstone.		
61.5 - 62.2	Green, glauconitic, silty, well-sorted, fine sand, with poorly cemented (sandstone) laminae.	32-50/5 in. (82) ~ 100	47

Recovered Sample Depth Below Ground Surface	Lithologic Description	Penetration Resistance (18-inch samples)	Sample Recovery (Percent)
67.5 - 68.2	Green, glauconitic, silty, well-sorted, fine sand, with poorly cemented (sandstone) laminae and a thin (0.05 ft.) fine-grained layer of green, glauconitic sandstone.	27-35-42 (77)	47
69.5	Thin layer of sandstone. Determined by drilling resistance.		

Base of Aquifer (Peedee Formation)
(73.5 ft. - termination)

Recovered Sample Depth Below Ground Surface	Lithologic Description	Penetration Resistance (18-inch samples)	Sample Recovery (Percent)
73.5	Thin laminae of green, glauconitic, very fine sand with dark green silt.	50/2 in. (100)	Shoe

Note: Penetration rate decreases.

Recovered Sample Depth Below Ground Surface	Lithologic Description	Penetration Resistance (18-inch samples)	Sample Recovery (Percent)
76.0 - 76.8	Green glauconitic, very silty, well-sorted, fine sand.	23-40-50 (90)	53

Boring Termination Depth: 77.5 feet below ground surface

Abandonment Procedure: 376 lbs. of Type I Portland Cement was mixed with approximately 30 gallons of water. The neat cement slurry was pumped through the drill stem from the borehole bottom up to the ground surface.

FROM 30' bgs to B.T.

BLOWS/6": $\bar{X}$ = 33.4 MAX: 50 N: $\bar{X}$ = 45.8 MAX: 100
SD = 12 MIN: 8 SD = 25 MIN: 8

EXPLORATORY SOIL BORING: AREA 3
(WELLS CW-3A, CW-3B)

Date Drilled: November 4, 1989
Plant Coordinates: N3340; E12,717.7
Approximate Ground Elevation: 39

RTI Project No. 4419-006

Recovered Sample Depth Below Ground Surface	Lithologic Description	Penetration Resistance (18-inch samples)	Sample Recovery (Percent)
	Surficial Aquifer (0 - 18 ft.)		
3.5 - 4.5	Tan, medium to coarse sandy clay.	2-4-6 (	63
8.5 - 10.0	Light tan to light brown, slightly silty, poorly sorted, slightly glauconitic, medium to fine sand. Nitrate not detected.	12-14-17	50
13.5 - 13.65	Tan, poorly sorted, slightly glauconitic, slightly clayey, medium to fine sand.	7-10-12	30
13.65 - 13.85	Gray, poorly sorted, glauconitic, slightly clayey and silty, fine to medium sand.		
13.85 - 13.95	Light brown, slightly glauconitic, slightly silty, coarse to medium sand. Nitrate detected.		

Recovered Sample Depth Below Ground Surface	Lithologic Description	Penetration Resistance (18-inch samples)	Sample Recovery (Percent)
	Semiconfining Unit (18.0 - 20.0 ft.)		
18.0 - 19.0	Gray, glauconitic, silty, fine sandy, dense clay with some fine-coarse rootlets. Upon re-entry bit hang from 18 ft. to 20 ft.	3-5-8	60
	Principal Aquifer (Peedee Formation) (23.5 - 54.5 feet)		
23.5 - 24.1	Tan and gray, glauconitic, very clayey, fairly well sorted, coarse sand, with some fine gravel.	4-4-2	60
24.1 - 24.3	Gray, glauconitic, very clayey, coarse to very coarse sand, with some fine gravel.		
24.3 - 24.5	Gray, glauconitic, silty, coarse sandy, dense clay. Nitrate detected.		
24.5 - 24.65	Tan, glauconitic, slightly silty, coarse to very coarse, sand.		
24.65 - 24.9	Gray, glauconitic, silty, coarse sandy, dense clay. Nitrate detected.		
33.5 - 33.7	Greenish light brown, glauconitic, slightly silty, fairly well sorted, medium to coarse sand, with gray clay and fine gravel at base.	17-15-14	53
33.7 - 35.0	Light green-gray, glauconitic, poorly sorted, fine to very fine sand. Nitrate detected.		

Recovered Sample Depth Below Ground Surface	Lithologic Description	Penetration Resistance (18-inch samples)	Sample Recovery (Percent)
38.5 - 38.8	Light brown, glauconitic, slightly silty, fairly well sorted, medium to fine sand, with shell fragments.	16-30-23	100
38.8 - 38.95	Redish brown and gray, glauconitic, fine, very sandy, silty, dense clay.		
38.95 - 40.0	Brown-tan with green hue, glauconitic, silty, well-sorted, very fine to fine sand.		
43.5 - 45.0	Light green, glauconitic and micaceous, silty, fairly well sorted, very fine to fine sand. Nitrate detected.	27-20-24	40
48.5 - 50.0	Dark green, glauconitic, micaceous, slightly silty, fairly well sorted, very fine to fine sand. Nitrate not detected.	12-28-30	53
52.0	Drill resistance. Thin layer of sandstone. No sample taken.		
53.0 - 54.5	Dark green, glauconitic, well-sorted, fine to very fine-grained sandstone, with some shell fragments.	50/3 in.	

Boring Termination Depth: 54.5 feet below ground surface

Abandonment Procedure: 188 lbs. of Type I Portland Cement was mixed with approximately 20 gallons of water. The neat cement slurry was pumped through the drill stem from the borehole bottom up to the ground surface.

EXPLORATORY SOIL BORING: AREA 4
(WELLS CW-4B, CW-4C)

Date Drilled: November 2, 1989
Plant Coordinates: N4670; E12,612
Approximate Ground Elevation: 27.5

RTI Project No. 4419-006

Recovered Sample Depth Below Ground Surface	Lithologic Description	Penetration Resistance (18-inch samples)	Sample Recovery (Percent)
	Fill (Road Bed) (0 - 4.5 ft.)		
0 - 1.5	Tan, clayey, medium sand with fine gravel and rootlets. (Road bed)	1-2-2	40
1.5 - 1.6	Tan, clayey, medium sand with rootlets. (Road bed)	1-1-1	67
3.0 - 4.5	Tan, clayey, medium sand with rootlets. (Road bed)	2-3-4	65
	Surficial Aquifer (0 - 9.4 ft.)		
4.5 - 6.0	Gray, glauconitic, slightly silty, fairly well sorted, medium-to-fine sand with clayey medium-to-fine sand zones throughout sample.	7-12-11	40
6.0 - 7.5	Gray, glauconitic, slightly silty, fairly well sorted, medium-to-fine sand with clayey medium-to-fine sand zones throughout sample.	5-6-4	40

Recovered Sample Depth Below Ground Surface	Lithologic Description	Penetration Resistance (18-inch samples)	Sample Recovery (Percent)
7.5 - 9.0	Mottled black and gray, silty, well-graded, medium-to-fine sand, with zones of very silty and clayey fine sand. Nitrate not detected.	6-9-8	67
9.0 - 9.4	Greenish gray, slightly glauconitic, mottled brown, fairly well sorted, medium-to-fine, clayey sand.	3-3-5	40
	Semiconfining Unit (9.4 - 14.65 ft.)		
9.4 - 10.5	Greenish gray, slightly glauconitic, medium to fine very sandy clay.		
10.5 - 10.65	Gray, slightly glauconitic, silty and clayey, fine-to medium sand.	1-2-2	65
10.65 - 11.05	Gray, slightly glauconitic, fine, sandy, dense clay.		
11.05 - 11.15	Blue-gray, slightly glauconitic, very sandy, soft clay.		
11.15 - 11.40	Dark gray, slightly glauconitic, fine, sandy, dense clay.		
12.0 - 12.75	Greenish, gray, slightly glauconitic, silty, very fine sandy, dense clay.	1-2-3-3	73
12.75 - 13.10	Blue-gray, slightly glauconitic, very fine sandy, dense clay.		
13.5 - 14.65	Blue-gray, slightly glauconitic very fine, slightly sandy, dense clay.	1-1-3	100

Recovered Sample Depth Below Ground Surface	Lithologic Description	Penetration Resistance (18-inch samples)	Sample Recovery (Percent)
	Principal Aquifer (Peedee Formation) ***(14.65 - 63.5 feet)***		
14.65 - 15.0	Gray, slightly glauconitic, very silty, clayey, very fine sand.		
15.0 - 15.75	Dark gray, slightly glauconitic, mottled light brown, silty, very fine sand, with thin, woody organic layers.	3-4-5	47
16.5 - 16.9	A thin layer of quartz gravel overlying a gray, slightly glauconitic, clayey, fine sand.	2-2-1	27
16.9 - 17.2	Dark green-gray, slightly glauconitic, silty and clayey, fine sand.		
18.0 - 19.5	Dark green, glauconitic, silty, fairly well sorted, fine to very fine sand. Nitrate not detected.	2-3-6	33
19.5 - 21.0	Dark green, glauconitic, silty, fairly well sorted, fine to very fine sand.	4-5-5	27
21.0 - 22.5	Dark green, glauconitic, silty, fairly well sorted, fine to very fine dark green sand.	3-3-6	40
22.5 - 22.8	Dark green, glauconitic, silty, fairly well sorted, fine to very fine sand.	4-6-9	47
22.8 - 23.5	Brown, glauconitic, silty, very fine sand. Nitrate not detected.		

Recovered Sample Depth Below Ground Surface	Lithologic Description	Penetration Resistance (18-inch samples)	Sample Recovery (Percent)
24.0 - 24.7	Light brown and tan with greenish hue, glauconitic, silty, very fine to fine sand.	4-15-21	47
25.5 - 27.0	Light brown with a greenish hue, glauconitic, silty, well-sorted, very fine sand. Nitrate not detected.	12-8-10	53
27.0 - 28.5	Light brown with a greenish hue, glauconitic, silty, well-sorted, very fine sand.	7-6-6	40
28.5 - 29.1	Light brown with a greenish hue, glauconitic, silty, well-sorted, very fine sand.	4-4-4	40
30.0 - 31.5	Dark green, glauconitic, silty, very fine sand with thin layer of dark green, fine-grained sandstone.	6-10-13	40
33.0 - 33.3	Sandstone layer. Determined by drilling resistance - no sample taken.		
34.8 - 35.0	Sandstone layer. Determined by drilling resistance - no sample taken.		
38.0 - 38.2	Sandstone layer. Determined by drilling resistance - no sample taken.	50/3.5 in.	None
39.8 - 40.0	Sandstone layer. Determined by drilling resistance - no sample taken.		

Recovered Sample Depth Below Ground Surface	Lithologic Description	Penetration Resistance (18-inch samples)	Sample Recovery (Percent)
41/5 - 41.6	Sandstone layer. Determined by drilling resistance - no sample taken.		
43.0 - 43.4	Dark green, micaceous, glauconitic, very silty, very fine sand with thin laminae of dark green silt. (Note: 8 mm. shell fragments found with fall-in of this sample.)	15-23-29	27
46.5 - 47.3	Sandstone layer. Determined by drilling resistance - no sample taken.		
48.5 - 48.58	Dark green, micaceous, glauconitic, very silty, fine sand.	23-28-36	0.05
50.1 - 50.3	Sandstone layer. Determined by drilling resistance - no sample taken.		
53.5 - 54.2	Dark green,micaceous, glauconitic, very silty, fine sand. (Note: Large shell fragments with some green clay fall-in from above this sample.)	30-40-36	47
58.5 - 60.0	Dark green, very silty, very fine sand.	25-50/5"	33
62.5 - 62.6	Sandstone layer. Determined by drilling resistance - no sample taken.		

Recovered Sample Depth Below Ground Surface	Lithologic Description	Penetration Resistance (18-inch samples)	Sample Recovery (Percent)
	Base of Aquifer (Peedee Formation) ***(63.5 ft. - termination)***		
63.5 - 64.2	Dark green to gray, very fine very sandy, silt.	19-20-27	47

Boring Termination Depth: 65 feet below ground surface

Abandonment Procedure: 376 lbs. of Type I Portland Cement was mixed with approximately 30 gallons of water. The neat cement slurry was pumped through the drill stem from the borehole bottom up to the ground surface.

EXPLORATORY SOIL BORING: AREA 5
(WELL CW-5B)

Date Drilled: January 16, 1990
Plant Coordinates: N5,320; E12,698
Approximate Ground Elevation: 32.0

RTI Project No. 4419-006

Recovered Sample Depth Below Ground Surface	Lithologic Description
	Surficial Aquifer (0 - 11.5 ft.)
5.0 - 6.0	Brown and gray, silty fine to medium sand.
7.5 - 8.5	Gray, silty, fine sand.
	Semiconfining Unit (11.5 - 19.7 ft.)
11.5 - 12.0	Gray, fine, sandy clay. (Clay started at 10.5 feet.)
14.0 - 15.0	Gray, fine, sandy clay, with wood.
15.0 - 16.0	Gray, fine sandy clay.
17.0 - 18.0	Gray, fine, sandy clay.
	Principal Aquifer (Peedee Formation) *(19.7 to termination)*
19.7 - 20.0	Gray, very clayey sand.

Recovered Sample Depth Below Ground Surface	Lithologic Description
27.0 - 28.0	Gray to light green, glauconitic, slightly silty, fine sand.

Boring Termination Depth: 28 feet below ground surface

Abandonment Procedure: 228 lbs. of Type I Portland Cement was mixed with approximately 14 gallons of water. The neat cement slurry was pumped through the drill stem from the borehole bottom up to the ground surface.

EXPLORATORY SOIL BORING: AREA 6
(WELLS CW-6A, CW-6B)

Date Drilled: November 1, 1989
Plant Coordinates: N5,363.23; E14,124.40
Approximate Ground Elevation: 28.5

RTI Project No. 4419-006

Recovered Sample Depth Below Ground Surface	Lithologic Description	Penetration Resistance (18-inch samples)	Sample Recovery (Percent)
	***Surficial Aquifer* (0 - 10.7 ft.)**	N	
0 - 1.0	Black, very silty, clayey, fine sand. Organic mat at surface (0.2 feet thick).	1-1-2 (3)	67
1.5 - 1.9	Black, very silty, clayey, fine sand.	1-1-1 (2)	100
1.9 - 3.0	Dark brown, silty, medium sand.		
3.85 - 4.1	Light brown mottled with thin tan layers, fine very sandy, clay.	1-1-2 (3)	73
4.5 - 4.9	Same as above, with rootlets.	2-11-13 (24)	73
4.9 - 5.6	Light brown, slightly silty, clayey, fairly well sorted medium to fine sand.		
6.0 - 6.8	Light brown, slightly silty, coarse to medium, well-sorted sand, with pink, coarse, well-rounded shell fragments.	6-10-12 (22)	53

Recovered Sample Depth Below Ground Surface	Lithologic Description	Penetration Resistance (18-inch samples)	Sample Recovery (Percent)
7.5 - 7.65	Light brown, slightly silty, coarse to medium, well-sorted sand, with pink, coarse, well-rounded shell fragments.	4-2-2 (4)	30
7.65 - 7.95	Black, mottled brown, very silty, very clayey, fairly well sorted and fine sand.		
9.0 - 10.0	Gray, clayey, well-sorted, fine to medium sand.	3-3-2 (5)	67
	***Semiconfining Unit* (10.5 - 14.7 ft.)**		
10.5 - 10.7	Gray, very clayey, medium to coarse sand.	2-4-2 (6)	80
10.7 - 11.1	Gray, very sandy, clay.		
11.1 - 11.3	Gray, clayey, coarse to medium sand, with rootlets.		
11.3 - 11.7	Gray, silty, slightly fine sandy, clay.		
12.0 -12.49	Gray and green, glauconitic, medium to fine, sandy clay.	1-2-4 (6)	67
12.49 - 12.50	Gray/white, well-sorted, medium sand.		
12.5 - 13.0	Gray, medium to fine, sandy clay.		
13.5 - 14.7	Gray, silty, dense and soft sticky clay. Very little sand content.	1-2-3 (5)	80
	Principal Aquifer (Peedee Formation) ***(15.0 - 63 feet)***		
15.0 - 16.2	Mottled gray, black, and light brown, silty, slightly clayey, fairly well sorted medium to fine sand with some fine gravel.	2-5-2 (7)	80

Recovered Sample Depth Below Ground Surface	Lithologic Description	Penetration Resistance (18-inch samples)	Sample Recovery (Percent)
16.5 - 18.0	Gray and light green, glauconitic silty, very clayey, poorly sorted, medium to fine sand.	4-3-3 (6)	100
18.0 - 18.75	Gray and light green, glauconitic, very silty, poorly sorted, fine to medium sand with fine gravel and rootlets. Nitrate detected.	2-1-3 (4)	50
19.5 - 20.7	Gray and light green, glauconitic, very silty, poorly sorted, fine to medium sand with fine gravel and rootlets.	3-2-2 (4)	80
22.0 - 23.0	Gray and light green, glauconitic, silty, well-sorted, fine sand, with fine rootlets. Sample is clayey at top. Nitrate not detected.	4-3-4-5 (9)	50
24.0 - 24.7	Gray and light green, glauconitic, silty, well-sorted, fine sand, with fine rootlets. Mottled with some light brown fine to medium sand.	7-12-20 (32)	47
25.5 - 27.0	Gray and light green, glauconitic, silty, well-sorted, fine sand, with fine rootlets. Sample is clayey at top.	12-16-16 (38)	100
27.0 - 27.7	Gray and light green, glauconitic, silty, well-sorted, fine sand, with fine rootlets.	8-12-15 (27)	47
28.0 - 29.1	Gray and light green, glauconitic, silty, well-sorted, fine sand, with fine rootlets.	5-8-9 (17)	40

Recovered Sample Depth Below Ground Surface	Lithologic Description	Penetration Resistance (18-inch samples)	Sample Recovery (Percent)
30.0 - 30.7	Gray and light green, glauconitic, silty, well-sorted, fine sand, with fine rootlets. Some fine gravel at top of sample. Nitrate not detected.	4-7-12 (29)	47
31.5 - 32.1	Gray and light green, glauconitic, silty, well-sorted, fine sand, with fine rootlets.	14-31-35 (66)	40
37.5 - 38.0	Sandstone. Determined by drill resistance.		
38.0 - 38.5	Gray and light green, mottled with light brown glauconitic, silty, well-sorted fine sand, with fine well-rounded shell fragments.	25-50/4.5" (50-100)	33
43.0 - 43.6	Gray and light green, mottled with light brown glauconitic, silty, well-sorted fine sand, with fine well-rounded shell fragments.	12-14-19 (33)	40
45.3 - 45.5	Sandstone. Determined by drilling resistance.		
48.0 - 48.4	Green, glauconitic, silty, well-sorted, very fine sand. Sample is clayey in discrete zones.	1-50/1" (100)	27
49.5 - 49.6	Sandstone. Determined by drilling resistance.		
52.3 - 52.5	Sandstone. Determined by drilling resistance.		
53.0 - 53.4	Green, glauconitic, very silty, very fine, well-sorted sand.	24-50/6" (100)	27

Recovered Sample Depth Below Ground Surface	Lithologic Description	Penetration Resistance (18-inch samples)	Sample Recovery (Percent)
56.0	Thin sandstone layer. Determined by drilling resistance.		
58.0 - 58.8	Green, glauconitic, very silty, well sorted, very fine sand.	27-34-40 (74)	53
	Base of Aquifer (Peedee Formation) ***(63 - Termination)***		
63.0 - 64.5	Green, glauconitic, fine very sandy silt, with thin layer of medium well-rounded to sub-rounded shell fragments (0.02').	5-9-10 (19)	100
64.5 - 65.3	Green, glauconitic, fine very sandy silt.	7-9-12 (21)	53
68.5 - 70.0	Green, glauconitic, fine very sandy silt. Sample is more sandy. Nitrate not detected.	7-8-18 (26)	100
73.5 - 74.7	Green, glauconitic, fine very sandy silt. Nitrate not detected.	25-33-50 (83)	80
78.5 - 79.15	Green, glauconitic, fine very sandy silt	50/6" 37-~~5/6~~" (100)	43
88.5 - 88.9	Green, glauconitic, fine, very sandy silt.Thin cemented sand laminae.	50/4.5" (100)	27
90.2 - 90.6	Sandstone. Determined by drill resistance.	(100)	
90.6 - 90.8	Green, glauconitic, fine, very sandy silt.	38-14-6 (20)	20

Recovered Sample Depth Below Ground Surface	Lithologic Description	Penetration Resistance (18-inch samples)	Sample Recovery (Percent)
93.5 - 94.5	Green, glauconitic, fine, very sandy silt. Nitrate not detected.	18-34-43 (77)	67
98.5 - 98.9	Green, glauconitic, fine, very sandy silt.	28-41-45 (86)	27
107-108.5	Green, glauconitic, fine, very sandy silt, with some medium sand.	11-21-33 (54)	100
118.5 - 120.0	Green, glauconitic, fine, very sandy silt, with some medium sand. Nitrate not detected.	14-31-50/5" (85)	100
128.5 - 130.0	Green, glauconitic, very sandy, slightly clayey silt.	7-9-13 (22)	100
138.5 - 140.0	Green, glauconitic, very sandy, slightly clayey silt.	6-9-11 (20)	100
153.5 - 155.0	Green, glauconitic, very sandy, slightly clayey silt.	10-12-15 (27)	100

Boring Termination Depth: 155 feet below ground surface

Abandonment Procedure: 376 lbs. of Type I Portland Cement was mixed with 30 gallons of water. The neat cement slurry was pumped through the drill stem to the borehole bottom and up to the ground surface.

Historical WT Area Lithologic Logs

Borings/Monitoring Wells

Logging Performed by Law Engineering

Boring	Well Numbers*
MW-1	MW-1B
MW-2	MW-2A
MW-3	MW-3A
MW-4	MW-4A, MW-4B
WT-4	WT-4

* see Figure 1-2 for well location

GEOPHYSICAL LOG INTERPRETATION

DEPTH FT.	MATERIAL DESCRIPTION	ELEV.	ESTIMATED PERMEABILITY k, CM/SEC	REMARKS
.0		29	No data	"Upper Sand"
4.0	Sand		$3x10^{-2}$	Range=$1x10^{-2}$ - $1x10^{-1}$
8.0	Sand With Clay	19	$2x10^{-4}$	Range=$1x10^{-4}$ - $1x10^{-3}$
14.5	Clay		$2x10^{-6}$	"Clay Layer" Range=$1x10^{-6}$ - $1x10^{-5}$
16.5	Sand	9 -1 -11	$1.5x10^{-3}$	Castle Hayne Formation "Lower Sand" Range=$7x10^{-4}$ - $7x10^{-3}$
39.0	Sand And Silt With Clay	-21 -31	$8x10^{-5}$ Grading To $2x10^{-6}$	Pee Dee Formation "Lower Sand" Range=$3x10^{-5}$ - $3x10^{-4}$ Range=$1x10^{-6}$ - $1x10^{-5}$
67.0	Boring Terminated	-41		

JOB NO. RA-1440 DATE 7/27/79 PAGE 1 OF 1 BORING NO. MW-1

LAW ENGINEERING TESTING COMPANY

GEOPHYSICAL LOG INTERPRETATION

DEPTH FT.	MATERIAL DESCRIPTION	ELEV.	ESTIMATED PERMEABILITY k, CM/SEC	REMARKS
.0	Sand	34 24 14	$3x10^{-3}$	"Upper Sand" Range=$2x10^{-3}$ - $2x10^{-2}$
22.0	Clay	4	$5x10^{-5}$	"Clay Layer" Range=$1x10^{-5}$ - $1x10^{-4}$
29.0	Sand With Clay	-6 -16	$2x10^{-3}$	Castle Hayne Formation "Lower Sand" Lab k =$4.28x10^{-4}$ Range=$7x10^{-4}$ - $7x10^{-3}$
50.0	Sand And Silt With Clay	-26 -36 -46	$8x10^{-5}$ Grading To 6x10-6	Pee Dee Formation "Lower Sand" Range=$3x10^{-5}$ - $3x10^{-4}$ Range=$3x10^{-6}$ - $3x10^{-5}$
78.0	Boring Terminated			

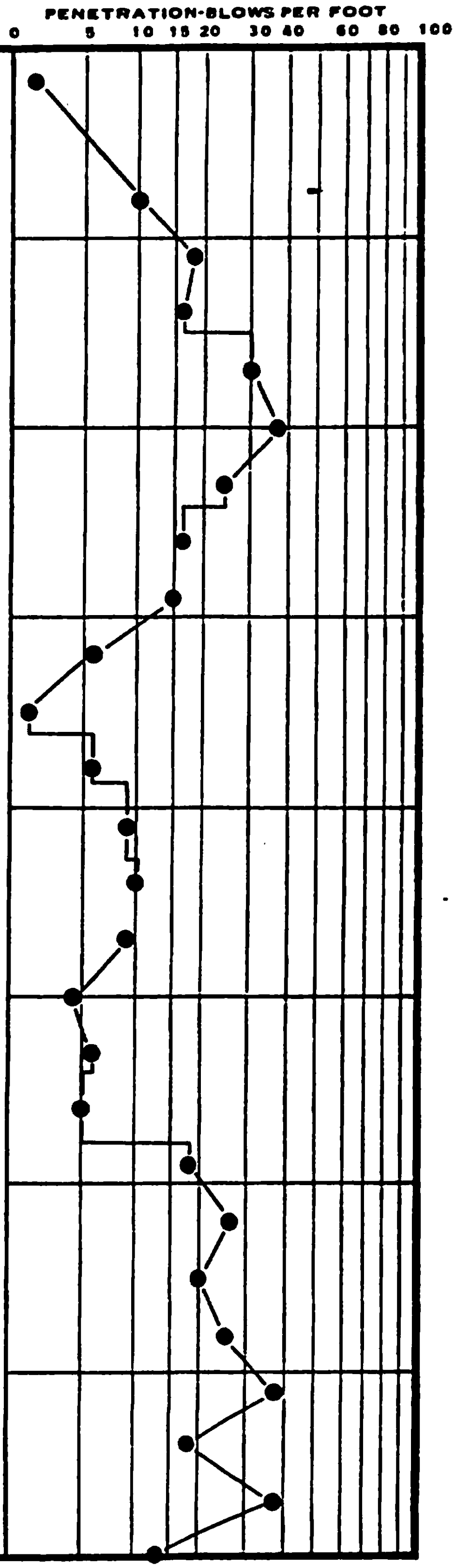
JOB NO. RA-1440 DATE 7/27/79 PAGE 1 OF 1 BORING NO. MW-2

LAW ENGINEERING TESTING COMPANY

GE790917

TEST BORING RECORD

ELEV.	DEPTH FEET	DESCRIPTION
39.5	0.5	TOPSOIL
		BROWN-YELLOW CLAYEY FINE TO MEDIUM SAND (SC)
34.5		
	7.5	
		YELLOW-BROWN FINE TO MEDIUM SAND (SP)
29.5		
	12.0	CLAYEY SAND (SC)
	12.5	LIGHT YELLOW-BROWN CLAYEY MEDIUM SAND (SC)
24.5	14.5	YELLOW MEDIUM TO FINE SILTY SAND (SM)
	18.0	
	19.3	FINE TO MEDIUM SAND (SP)
19.5		LIGHT YELLOW BROWN CLAYEY SILTY FINE SAND (SM-SC)
	21.4	CLAYEY SAND (SC)
16	23.5	
14.5		SANDY CLAY (CL)
	25.2	LIGHT YELLOW BROWN SILTY CLAY, TRACE OF FINE SAND (CH)
	27.0	FINE TO MEDIUM SAND (SP)
	27.5	LIGHT YELLOW BROWN FINE SAND, TRACE OF SILT (SP)
	28.7	
9.5		FINE TO DENSE BROWN, TAN GRAY AND GRAY BROWN FINE SAND (SP) (POSSIBLY CASTLE HAYNE FORMATION) (27.0 - 57.0 FEET)
4.5		
-0.5		



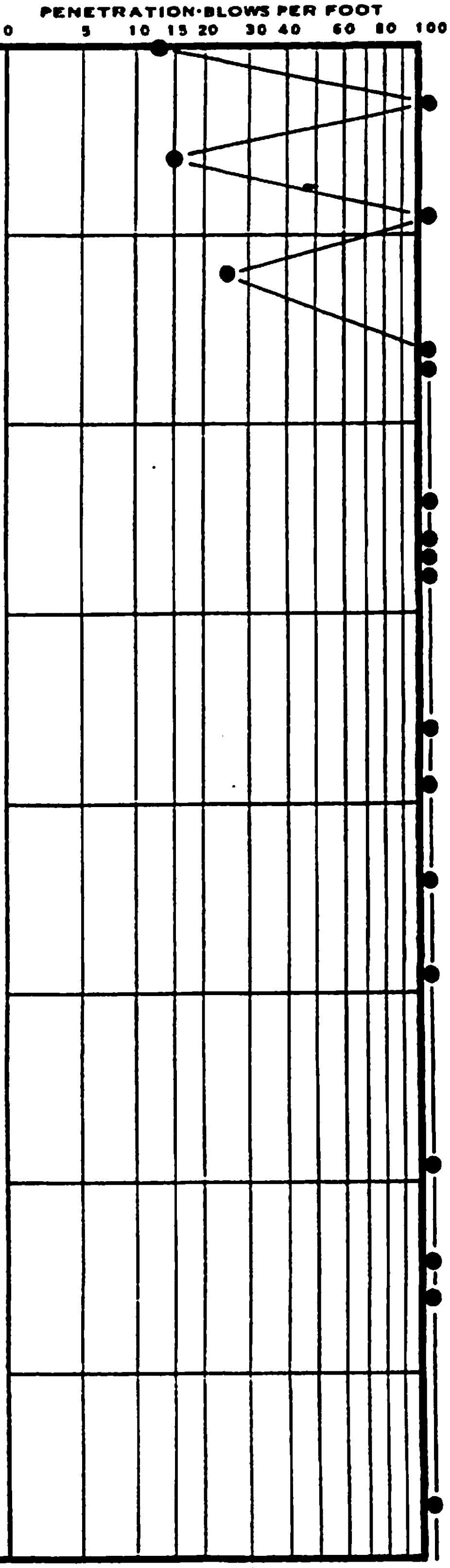
REMARKS:

DRILLED BY Dew
LOGGED BY Dhunjishah
CHECKED BY Tice

BORING NUMBER MW-3
DATE STARTED 5/15/79
DATE COMPLETED 5/16/79
JOB NUMBER RA-1440

TEST BORING RECORD

ELEV.	DEPTH FEET	DESCRIPTION
-5.5		
	47.5	VERY DENSE GRAY BROWN AND GRAY FINE SAND WITH CEMENTED ZONES AND SOME SHELL FRAGMENTS (SP) (CASTLE HAYNE FORMATION)
-10.5		
-15.5		
	57.0	VERY DENSE OLIVE, OLIVE GRAY AND DARK GRAY SILTY FINE SAND (SP-SM) (PEE DEE FORMATION)
-20.5		
-25.5		
-30.5		
-35.5		
-40.5		



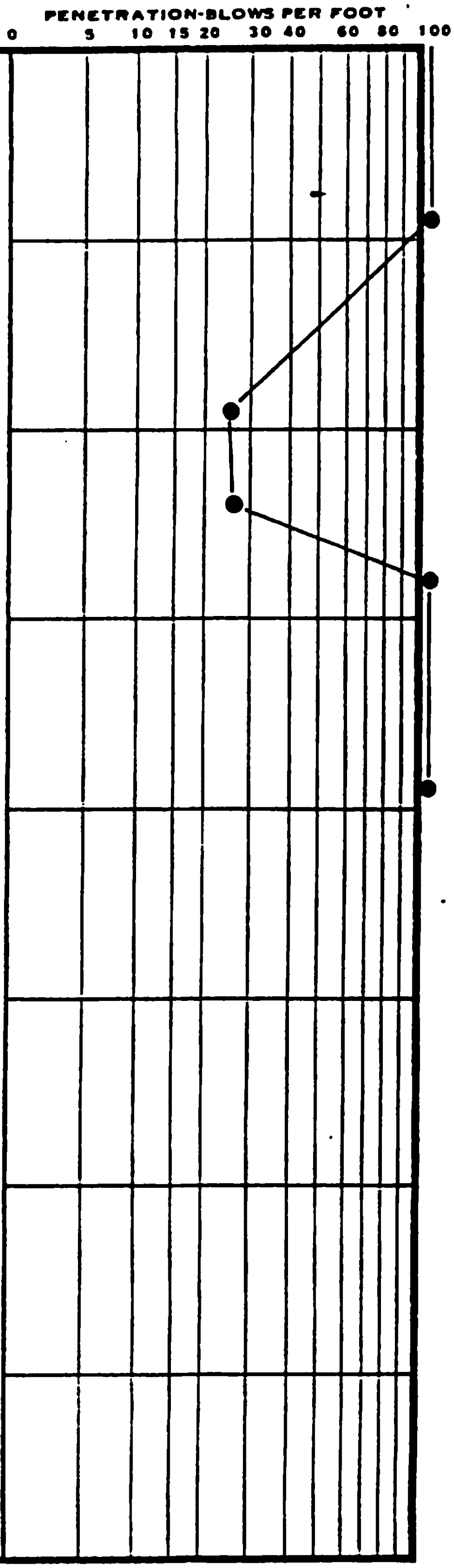
REMARKS:

DRILLED BY Dew
LOGGED BY Dhunjishah
CHECKED BY Tice

BORING NUMBER MW-3
DATE STARTED 5/15/79
DATE COMPLETED 5/16/79
JOB NUMBER RA-1440

TEST BORING RECORD

ELEV.	DEPTH FEET	DESCRIPTION
	83.5	
-45.5		DENSE TO VERY DENSE DARK GRAY AND BLACK SILTY FINE SAND (SM) (PEE DEE FORMATION)
-50.5		
-55.5		
-60.5	100.0	BORING TERMINATED



REMARKS:

DRILLED BY Dew
LOGGED BY Dhunjishah
CHECKED BY Tice

BORING NUMBER MW-3
DATE STARTED 5/15/79
DATE COMPLETED 5/16/79
JOB NUMBER RA-144C

GEOPHYSICAL LOG INTERPRETATION

DEPTH FT.	MATERIAL DESCRIPTION	ELEV.	ESTIMATED PERMEABILITY k, CM/SEC	REMARKS
0.0	No data	39.5		
	Sand	29.5 19.5	$2x10^{-2}$	"Upper Sand" Lab k = $1.86x10^{-2}$ cm/sec Range=$8x10^{-3}$ - $8x10^{-2}$
20.0	Clay	10.5	$3x10^{-5}$ with a peak value at $1x10^{-6}$	"Clay Layer" Lab k = $1.06x10^{-6}$ cm/sec Range=10^{-5} - 10^{-4}
30.0	Sand With Clay	0.5 -9.5 -19.5	$3x10^{-3}$	Castle Hayne Formation "Lower Sand" Lab k = $2.56x10^{-3}$ cm/sec Range=$2x10^{-3}$ - $2x10^{-2}$
60.0	Silty Sand And Sandy Silt With Clay	-29.5 -39.5	$8x10^{-5}$ Grading To	Pee Dee Formation "Lower Sand" Range=$3x10^{-5}$ - $3x10^{-4}$

JOB NO. RA-1440 DATE 7/24/79 PAGE 1 OF 2 BORING NO. MW-3

LAW ENGINEERING TESTING COMPANY

GEOPHYSICAL LOG INTERPRETATION

DEPTH FT.	MATERIAL DESCRIPTION	ELEV.	ESTIMATED PERMEABILITY k, CM/SEC	REMARKS
	See Previous Page		$1.5\text{x}10^{-6}$	Range=$7\text{x}10^{-7}$ - $7\text{x}10^{-6}$
99.0	Boring Terminated	-49.5		

JOB NO. RA-1440 DATE 7/27/79 PAGE 2 OF 2 BORING NO. MW-3

GEOPHYSICAL LOG INTERPRETATION

DEPTH FT.	MATERIAL DESCRIPTION	ELEV.	ESTIMATED PERMEABILITY k, CM/SEC	REMARKS
0		39	No data	"Upper Sand"
5.0	Sand	29 19	$1x10^{-2}$	Range=$5x10^{-3}$ - $5x10^{-2}$
20.0	Clay	9	$3x10^{-5}$	"Clay Layer" Range=$1x10^{-5}$ - $1x10^{-4}$
31.0	Sand	-1 -11	$1x10^{-3}$	Castle Hayne Formation "Lower Sand" Range=$4x10^{-4}$ - $4x10^{-3}$
57.0	Sand And Silt With Clay	-21 -31 -41	$8x10^{-5}$ Grading To	Pee Dee Formation "Lower Sand" Range=$3x10^{-5}$ - $3x10^{-4}$

JOB NO. RA-1440 DATE 7/27/79 PAGE 1 OF 2 BORING NO. MW-4

LAW ENGINEERING TESTING COMPANY

GEOPHYSICAL LOG INTERPRETATION

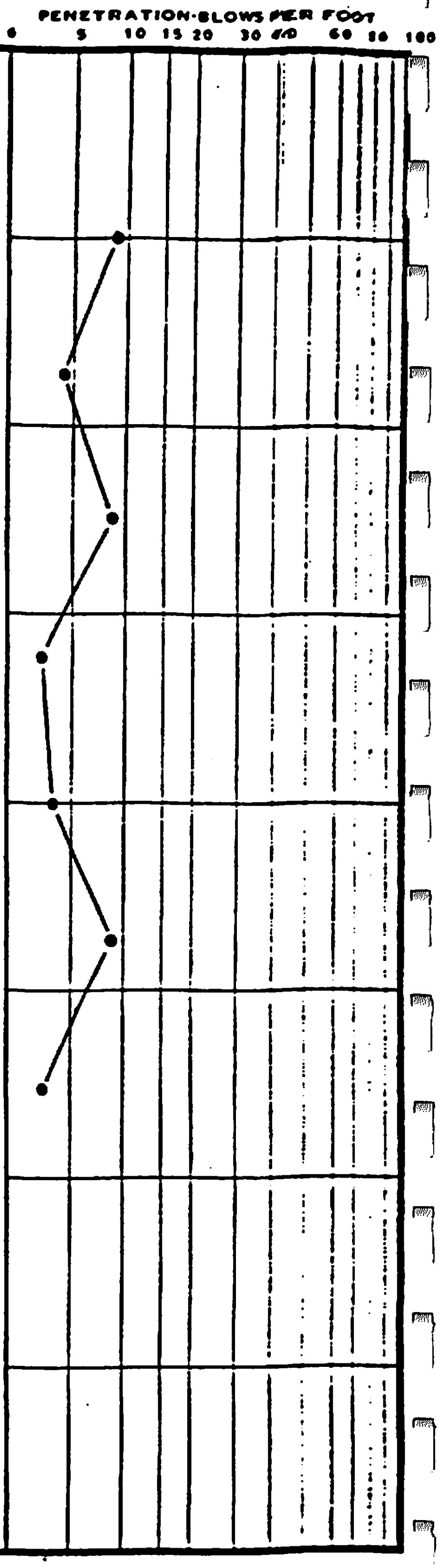
DEPTH FT.	MATERIAL DESCRIPTION	ELEV.	ESTIMATED PERMEABILITY k, CM/SEC	REMARKS
	See Previous Page			
		-51		
		-61		
		-71		
		-81	$1.5x10^{-6}$	
				Range=$7x10^{-7}$ - $7x10^{-6}$
129.0		-91		
	Boring Terminated			

JOB NO. RA-1440 DATE 7/27/79 PAGE 2 OF 2 BORING NO. MW-4

LAW ENGINEERING TESTING COMPANY

TEST BORING RECORD

ELEV.	DEPTH FEET	DESCRIPTION	
		Loose fill with sand and gravel	
	2.0	Dark brown organic stained slightly silty fine sand	
	4.0	Brown to dark brown organic stain slightly silty fine sand with some gray clayey sand inclusions	
	6.0	Brown to dark brown slightly fine sand with some gray clayey sandy inclusions to black organic clayey silt with fiberous organic matter	
	8.0	Black organic slightly sandy clayey silt to light brown to gray fine to medium sand	▽
	10.0	Light brown fine to medium sand	
		Dark gray slightly clayey very silty fine sand with wood fragments	
	12.0		



REMARKS:

▽ Water surface at time of drilling.

DRILLED BY ______

LOGGED BY R.W. Olson

CHECKED BY ______

BORING NUMBER WT-4

DATE STARTED 12-14-84

DATE COMPLETED 12-14-84

JOB NUMBER ME4312

Figure 6

Appendix D

July 9, 1999, Memorandum
Discussion of Water-Table Configuration

RESEARCH TRIANGLE INSTITUTE

Center for Environmental Measurements and Quality Assurance

Memorandum

July 9, 1999

To: Herb Strickler, Manager
Site Environment, Health and Safety

From: Jeff Reynolds, P.G., P.HG. for
Project Hydrogeologist

Subject: Discussion of Water-Table Configuration
Waste Treatment Nitrate Basin Area
RTI Project 6448-019

This memorandum summarizes technical information pertaining to the configuration of the water table beneath General Electric's (GE's) waste treatment (WT) basin area. This information was requested by the North Carolina Department of Environment and Natural Resources (DENR), Groundwater Section during a meeting attended by representatives of GE, DENR, and Research Triangle Institute (RTI) at DENR's Wilmington Regional Office on June 10, 1999.

One of the topics discussed during the June 10 meeting was the possibility that the mounding pattern typically observed in the surficial aquifer beneath the WT facility might be due to leakage from one or both of the lined WT basins. In response to this hypothesis, RTI further studied the soils and groundwater levels in the WT area; this study is discussed in greater detail below. On the basis of that study, we have interpreted that the position of the drainage ditches surrounding the WT facility, not leakage from the lined basins, is the primary cause of the mounding pattern -- it is inferred that the presence of the drainage ditches causes the water table to be deflected downward toward the elevation of the ditches.

Background Information

During the June 10, 1999, meeting, GE notified DENR that principal-aquifer groundwater beyond the 500-foot compliance boundary of the WT area has been impacted by nitrate and ammonia and that historical leakage from one or both of the lined nitrate liquid basins

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is the suspected source of the contamination. DENR was informed of the current mapped extent of nitrate and ammonia in groundwater (limited to the interior of the GE site), and that there are no human receptors immediately downgradient of the area. Technical information was summarized in a document entitled *Summary of Initial Assessment Activities - Waste Treatment Basin Area* (RTI Document No. 6448-019/001/01F) -- a copy of the document was provided to DENR during the meeting. Furthermore, DENR was informed that the west nitrate basin was relined in August of last year and that the east nitrate basin was recently drained in order to initiate relining of that basin as well. Relining of the east basin was completed July 8, 1999.

During the meeting, Dr. Charles Stehman of DENR inquired about the apparent mounding of the water table beneath the WT area (as portrayed on pages 6 and 15 of the document provided during the meeting). Specifically, he inquired whether water levels in the surficial aquifer had been measured after the basin had been drained to ascertain whether the mounding was a result of fluid leakage from the basin. With GE's concurrence, RTI indicated that additional water levels in the area would be measured and evaluated, and GE informed DENR that results of the evaluation would be forwarded to DENR. RTI suggested that the apparent mounding could also be resultant of a higher-elevated clayey layer beneath the nitrate basins or groundwater discharge to shallow drainage ditches that surround the WT area. Before the WT facility was constructed, there were no natural stream channels at that location. In order to protect the WT facility berm from erosion by stormwater, drainage ditches were excavated around the base of the berm at the time the facility was constructed in order to collect stormwater runoff from the surrounding area. The excavated depth of these drainage ditches penetrated the water table, and surficial-aquifer groundwater now seeps into these ditches (the drainage ditches have become "gaining streams").

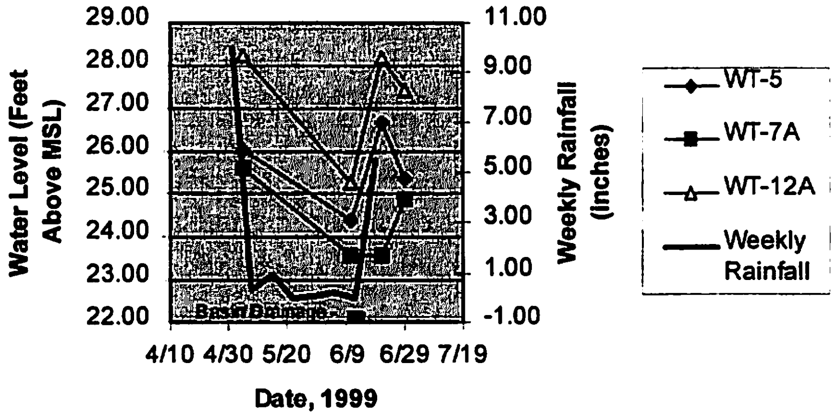
Activities Completed

Water levels in monitoring wells surrounding the WT basins were measured on June 11th. In addition, because the east nitrate basin was recently drained (beginning a few days prior to the meeting) and being prepared for relining, hand auger borings were advanced through the bottom of the basin to evaluate the depth and/or presence of a clayey semiconfining layer(s) and to obtain water levels directly below the east nitrate basin (for comparison to surrounding surficial-aquifer groundwater elevations). These hand-auger borings and additional water-level measurements were completed on June 21-22, 1999. An additional set of water-levels (from three adjacent monitoring wells) was measured on June 29, 1999.

Results

A short-term hydrograph for selected wells proximal to the east nitrate basin is provided in Figure 1. The hydrograph indicates that water levels were generally decreasing due to the lack of rain for at least one month prior to draining of the east nitrate basin. Rainfall events occurring after the east basin was drained resulted in the recovery of the water levels as indicated by the June 29, 1999, water levels.

Figure 1. WT East Nitrate Basin Area Water Levels



A cross-sectional view of the northeast corner of the east nitrate basin is provided as Figure 2. This figure is similar to the cross section included on page 15 of the document provided in the June 10th meeting and includes water levels measured in the hand-auger boring advanced in the northeast corner of the east nitrate basin and in monitoring wells located outside of the WT facility after the east nitrate basin was drained. The post-drainage water-table configuration is similar to that shown on page 15 of the meeting document (based on May 5, 1999, water levels). The elevation of the water table measured directly beneath the northeast corner of the east nitrate basin on June 21st was approximately 1 foot below the elevation of the water table inferred on page 15 of the meeting document. It should be noted that the elevation of the water table east of the north-flowing drainage ditch bordering the east side of the WT facility (as measured in well WT-12A) is consistently greater than the elevation of the water table below the east nitrate basin.

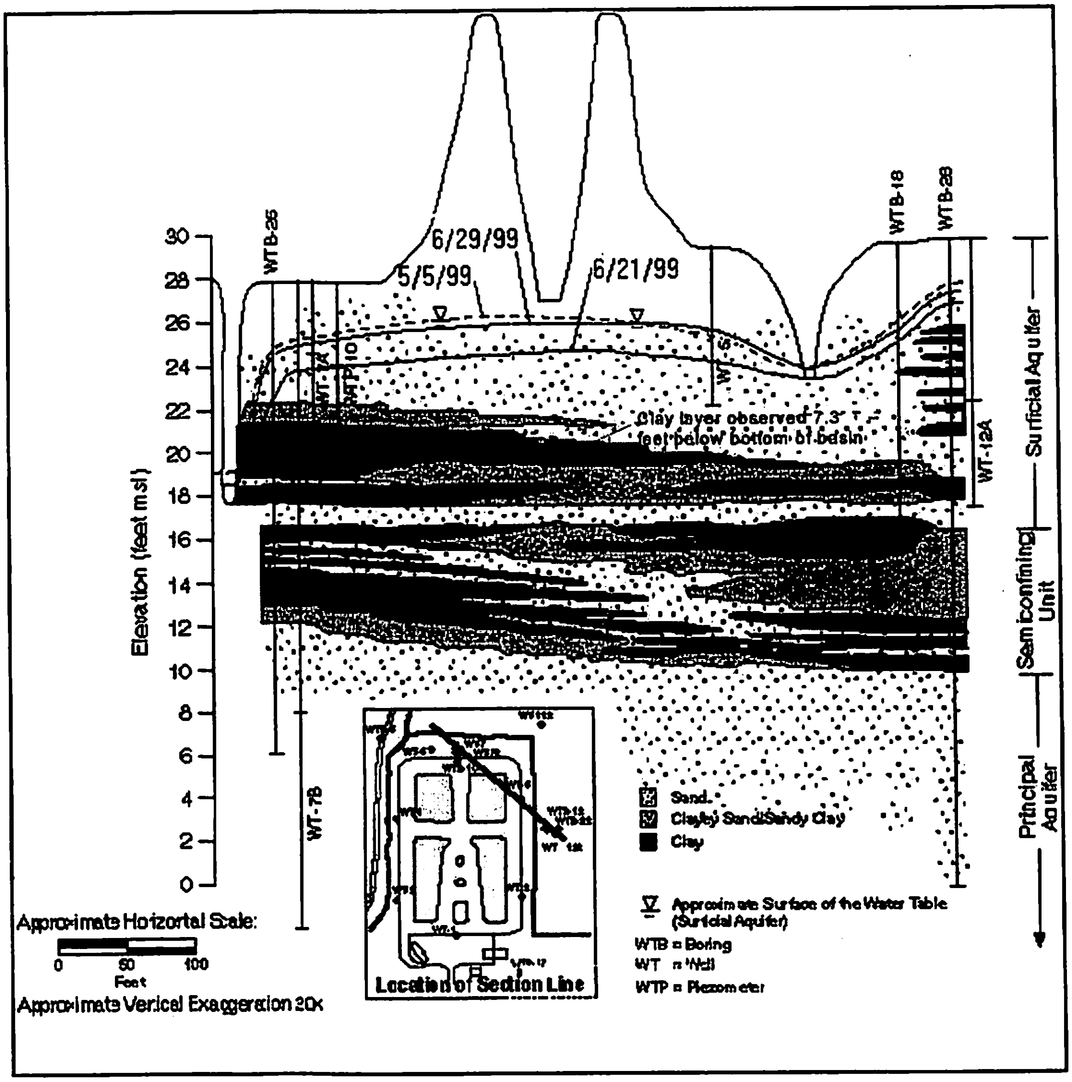


Figure 2. Generalized Cross Section Beneath NE Corner of East Nitrate Basin

Sandy clay was encountered in the boring advanced below the northeast corner of the east nitrate basin at a depth of approximately 7.3 feet below the bottom of the nitrate basin. Samples of sand between the bottom of the nitrate basin and the sandy clay layer were field- tested for nitrate using nitrate strips. Evidence of nitrate was detected in the sand samples, suggesting that nitrate has leaked from the basin in the past. In addition, a grab sample of the surficial aquifer groundwater in the boring indicated presence of nitrate at 14.7 mg/L (as N). Because the nitrate levels in the soil and groundwater encountered in the borehole above the clay were slightly elevated, the boring was not advanced through this greenish-gray sandy clay layer, and so the thickness of the semiconfining layer was not evaluated.

Conclusions

It is interpreted that the apparent mounding of the water table in the WT basin area is primarily attributed to the position of the drainage ditches surrounding the WT facility. Once excavated around the base of the WT facility berm to collect stormwater runoff from the surrounding area, these drainage ditches became gaining streams, thus causing the water table to be deflected downward toward the elevation of the drainage ditches.

Water levels alone cannot be used to conclude that the mounded configuration of the water table was a result of leakage from the nitrate basin. The presence of contamination in the surficial and principal-aquifer groundwater suggests that leakage from the basins may have contributed fluids to the water table beneath the east nitrate basin. However, the position of the drainage ditches surrounding the WT facility, not this leakage, is interpreted to be the primary cause of the mounding pattern typically observed in the surficial aquifer beneath the WT facility.

This memorandum summarizes pertinent information from recent field assessment activities completed in the area. Additional assessment activities in the WT area will continue and the results will be provided in a separate site investigation report. Please call me if you have any questions regarding the activities described in this memorandum.

cc: Tom Crawford
Dave Brown
Andrew Stahl
W.J. Alexander
G. Edward Story
File - Project 6448-019

Appendix E

Slug-Test Procedures and Results

Appendix E
Slug-Test Procedures and Results

E.1 Background Information

Estimates of aquifer hydraulic conductivity (K) in the Waste Treatment (WT) area of the General Electric site in Wilmington, North Carolina, have been obtained through the use of instantaneous displacement tests, commonly referred to as slug tests. A series of slug tests were performed on March 17-18, 1999, in the area surrounding the WT Facility. Slug tests were performed in 12 monitoring wells screened in the principal aquifer located throughout the WT area (BW-1B, CW-1B, CW-1C, CW-2B, CW-4B, CW-4C, CW-5B, MW-1B, MW-2B, WT-13B, WT-14B, and WT-7B).

E.2 Method Description

The slug tests were performed using a pneumatic displacement method rather than displacement with a solid slug. With the pneumatic method, the water level in a well is depressed by pressurizing the well casing with an inert gas (nitrogen was used for the testing described herein). The pneumatic slug test typically provides superior data quality relative to the typical displacement methods as it avoids problems such as:

- Insufficient and uncontrolled displacement of water,
- Non-instantaneous slug removal, and
- Interference with the pressure transducer cable.

After measuring the static water level in the well, an air-tight wellhead fitting is attached to top of the well casing. This wellhead fitting contains a pressure gauge, gas injection port, a sealed pressure transducer inlet, and a large (2-inch) ball valve for instantaneously releasing the pressure at the start of the slug test. The pressure transducer is lowered into the well casing to a depth below the anticipated displacement water level, connected to a data logger, referenced to zero, and programmed for data collection. After ensuring that the ball valve is closed, the well is pressurized to lower the water to the desired level (as measured on the pressure gauge reading inches of water pressure). The pressure is adjusted to the desired level (typically approximately 100 inches of water pressure, which equates to the displacement of the water column), ensuring that the water level is not pushed below the top of the screened interval of the well. Prior to initiating the actual slug test, the water level measured by the data logger is allowed to re-equilibrate to zero. After the water level stabilizes, the slug test is started by instantaneously releasing the pressure from the casing by opening the ball valve. The data logger is activated just before depressurization so that all early-time data are collected. The compressed air supply is then turned off, and data logging continues until the water level is near the initial, static condition. After testing, the transducer cable is removed and decontaminated (as necessary) and the well is resecured.

E.3 Data Analysis

The data were downloaded from the data logger onto a laptop PC and were plotted using Microsoft Excel. The Bouwer and Rice (1976) and the Hvorslev (1951) analysis methods were used to obtain K estimates. Charts illustrating the water level response to the slug tests are attached. The worksheets detailing the analyses for each test are also provided.

E.4 Results and Conclusions

Table 1 provides a summary of the calculated K values. The minimum and maximum K values are 4.1 and 34.2 ft/d, respectively. The geometric mean K values for the Hvorslev and Bouwer-Rice analysis methods were 16.8 and 11.1 ft/d, respectively.

E.5 References

Bouwer, H. and R.C. Rice. 1976. *A Slug Test for Determining Hydraulic Conductivity of Unconfined Aquifers with Completely or Partially Penetrating Wells.* US Water Conservation Laboratory. Phoenix AZ.

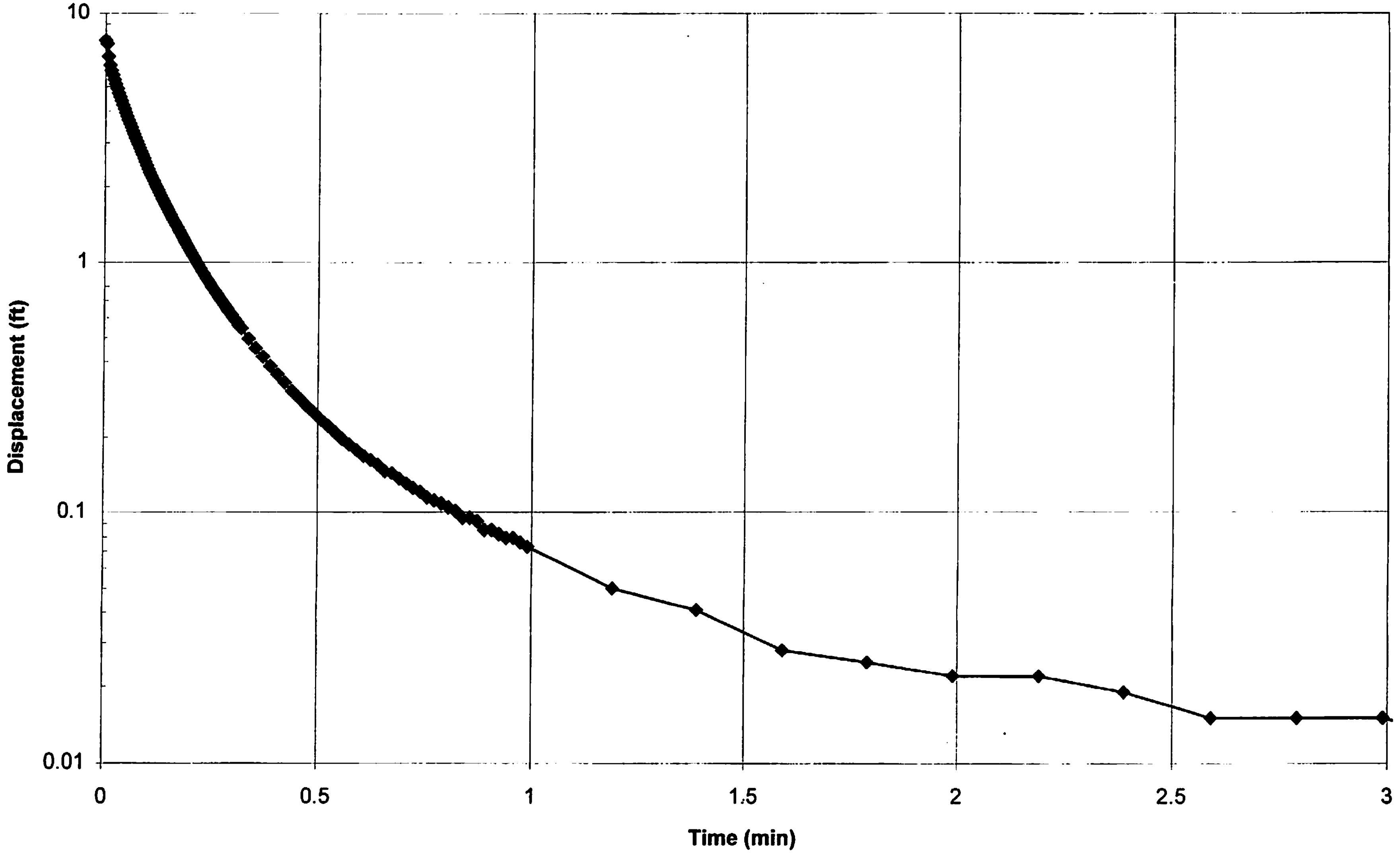
Hvorslev, M.J. 1951. *Time Lag and Soil Permeability in Ground-Water Observations.* Bulletin 36. US Army Corps of Engineers.

Table E-1
Summary of WT Area Slug Test Results

Well	Top of Screen (msl)	Bottom of Screen (msl)	Middle of Screen (msl)	Calculated Hydraulic Conductivity (ft/day)	
				Hvorslev Analysis Method	Bouwer-Rice Analysis Method
Wells screened deeper in the principal aquifer					
CW-1C	-7.8	-17.8	-12.8	7.7	6.3
CW-4C	-12.7	-22.7	-17.7	5.0	4.1
MW-1B	-1.2	-6.2	-3.7	12.1	7.8
MW-2B	-0.8	-5.8	-3.3	8.8	5.8
Geometric Mean (deeper wells)				**8.0**	**5.8**
Standard Deviation (deeper wells)				**2.9**	**1.5**
Wells screened shallower in the principal aquifer					
BW-1B	2.9	-7.2	-2.2	20.5	11.8
CW-1B	6.9	-3.1	1.9	21.3	13.5
CW-2B	7.0	-3.0	2.0	23.4	17.0
CW-4B	8.7	-1.3	3.7	26.0	16.4
CW-5B	6.9	-3.1	1.9	16.1	11.5
WT-13B	4.7	-4.8	0.0	28.3	16.6
WT-14B	3.2	-6.3	-1.6	34.2	19.6
WT-7B	7.2	-2.3	2.5	30.4	17.3
Geometric Mean (shallower wells)				**24.4**	**15.2**
Standard Deviation (shallower wells)				**5.9**	**2.9**
Geometric Mean (overall)				**16.8**	**11.1**
Standard Deviation (overall)				**9.6**	**5.3**

Note: This table presents results of pneumatic slug tests performed on March 17-18, 1999.
msl = Feet above mean sea level

BW-1B Slug Test Results
3/18/99



BW-1B Slug Test Analyses

BW-1B Bouwer-Rice Analysis

Casing Radius	Rc	0.0833	ft
Screen Length	L	10	ft
Borehole Radius	Rw	0.375	ft
Initial Drawdown	So	7.7	ft
Water Column Height	H	21.81	ft
Dimensionless constant	A	2.3	
Dimensionless constant	B	0.42	
Saturated Thickness	D	50	ft

Parameter used to determine the constants A and B
(from graph in Bouwer, 1976)

L/Rw	26.67

Ln Re/Rw = (1.1/ln(H/Rw) + (A+B*ln((D-H)/Rw))/(L/Rw))^-1

=	2.35

Point from time-drawdown curve used in solution:

Time	t	0.15	min
Drawdown	St	1.7	ft

Hydraulic Conductivity = (Rc^2*(Ln Re/Rw))/(2*L)*1/t*LN(So/St)

=	**0.00822086**	**ft/min**
=	**11.84**	**ft/day**

BW-1B Hvorslev Analysis

Well casing radius	r	0.0833	ft
Well bore radius	R	0.375	ft
Well screeen length	L	10	ft
Time to %37 of initial head change	To	0.08	min

Hydraulic Conductivity = r^2*LN(L/R)/(2*L*To)

=	**0.01423953**	**ft/min**
=	**20.50**	**ft/day**

CW-1B Slug Test Analyses

CW-1B Bouwer-Rice Analysis

Casing Radius	Rc	0.0833	ft
Screen Length	L	10	ft
Borehole Radius	Rw	0.375	ft
Initial Drawdown	So	7.9	ft
Water Column Height	H	23.14	ft
Dimensionless constant	A	2.3	
Dimensionless constant	B	0.42	
Saturated Thickness	D	50	ft

Parameter used to determine the constants A and B
(from graph in Bouwer, 1976)

L/Rw	26.67

Ln Re/Rw = (1.1/ln(H/Rw) + (A+B*ln((D-H)/Rw))/(L/Rw))^-1

=	2.38

Point from time-drawdown curve used in solution:

Time	t	0.17	min
Drawdown	St	1.15	ft

Hydraulic Conductivity = (Rc^2*(Ln Re/Rw))/(2*L)*1/t*LN(So/St)

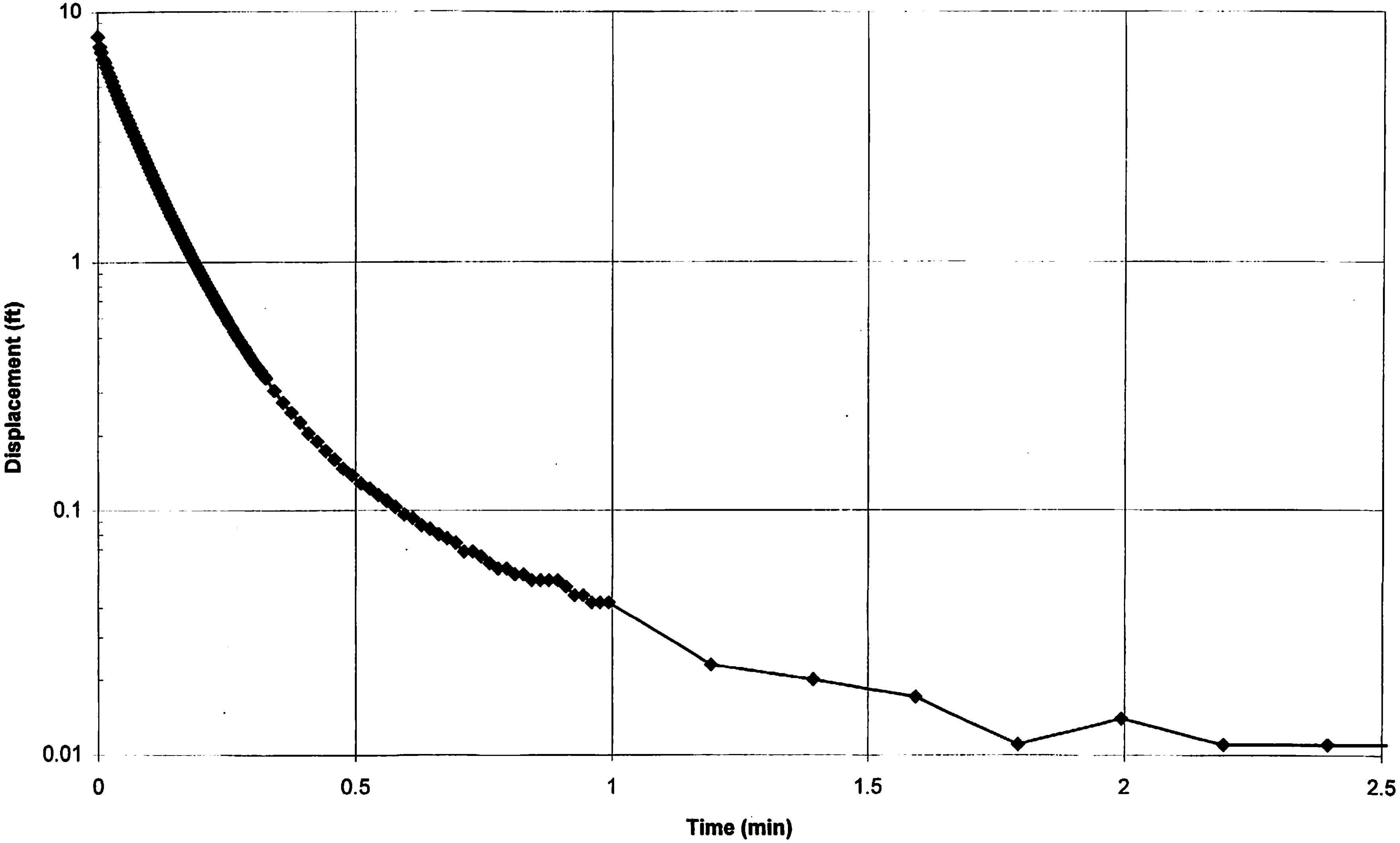
=	**0.00935606**	**ft/min**
=	**13.47**	**ft/day**

CW-1B Hvorslev Analysis

Well casing radius	r	0.0833	ft
Well bore radius	R	0.375	ft
Well screeen length	L	10	ft
Time to %37 of initial head change	To	0.077	min

Hydraulic Conductivity = r^2*LN(L/R)/(2*L*To)

=	**0.01479432**	**ft/min**
=	**21.30**	**ft/day**



CW-1B Slug Test Results
3/18/99

CW-1B Slug Test Analyses

CW-1B Bouwer-Rice Analysis

Casing Radius	Rc	0.0833	ft
Screen Length	L	10	ft
Borehole Radius	Rw	0.375	ft
Initial Drawdown	So	7.9	ft
Water Column Height	H	23.14	ft
Dimensionless constant	A	2.3	
Dimensionless constant	B	0.42	
Saturated Thickness	D	50	ft

Parameter used to determine the constants A and B
(from graph in Bouwer, 1976)

L/Rw	26.67

Ln Re/Rw = (1.1/ln(H/Rw) + (A+B*ln((D-H)/Rw))/(L/Rw))^-1

=	2.38

Point from time-drawdown curve used in solution:

Time	t	0.17	min
Drawdown	St	1.15	ft

Hydraulic Conductivity = (Rc^2*(Ln Re/Rw))/(2*L)*1/t*LN(So/St)

=	**0.00935606**	**ft/min**
=	**13.47**	**ft/day**

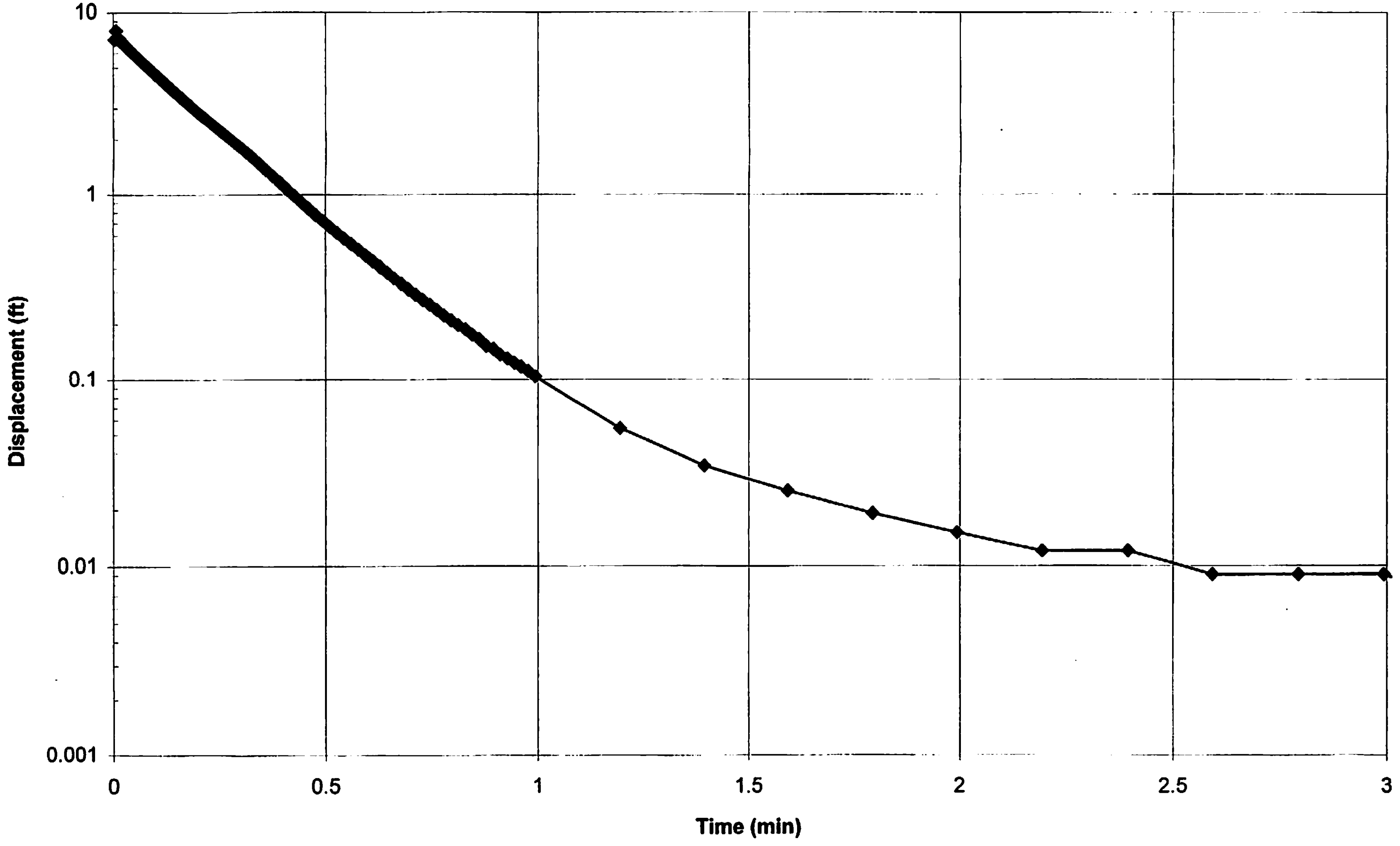
CW-1B Hvorslev Analysis

Well casing radius	r	0.0833	ft
Well bore radius	R	0.375	ft
Well screeen length	L	10	ft
Time to %37 of initial head change	To	0.077	min

Hydraulic Conductivity = r^2*LN(L/R)/(2*L*To)

=	**0.01479432**	**ft/min**
=	**21.30**	**ft/day**

CW-1C Slug Test Results
3/18/99



CW-1C Slug Test Analyses

CW-1C Bouwer-Rice Analysis

Casing Radius	Rc	0.0833	ft
Screen Length	L	10	ft
Borehole Radius	Rw	0.375	ft
Initial Drawdown	So	7.9	ft
Water Column Height	H	37.49	ft
Dimensionless constant	A	2.3	
Dimensionless constant	B	0.42	
Saturated Thickness	D	50	ft

Parameter used to determine the constants A and B
(from graph in Bouwer, 1976)

L/Rw	26.67

Ln Re/Rw = (1.1/ln(H/Rw) + (A+B*ln((D-H)/Rw))/(L/Rw))^-1

=	2.63

Point from time-drawdown curve used in solution:

Time	t	0.61	min
Drawdown	St	0.43	ft

Hydraulic Conductivity = (Rc^2*(Ln Re/Rw))/(2*L)*1/t*LN(So/St)

=	**0.00435256**	**ft/min**
=	**6.27**	**ft/day**

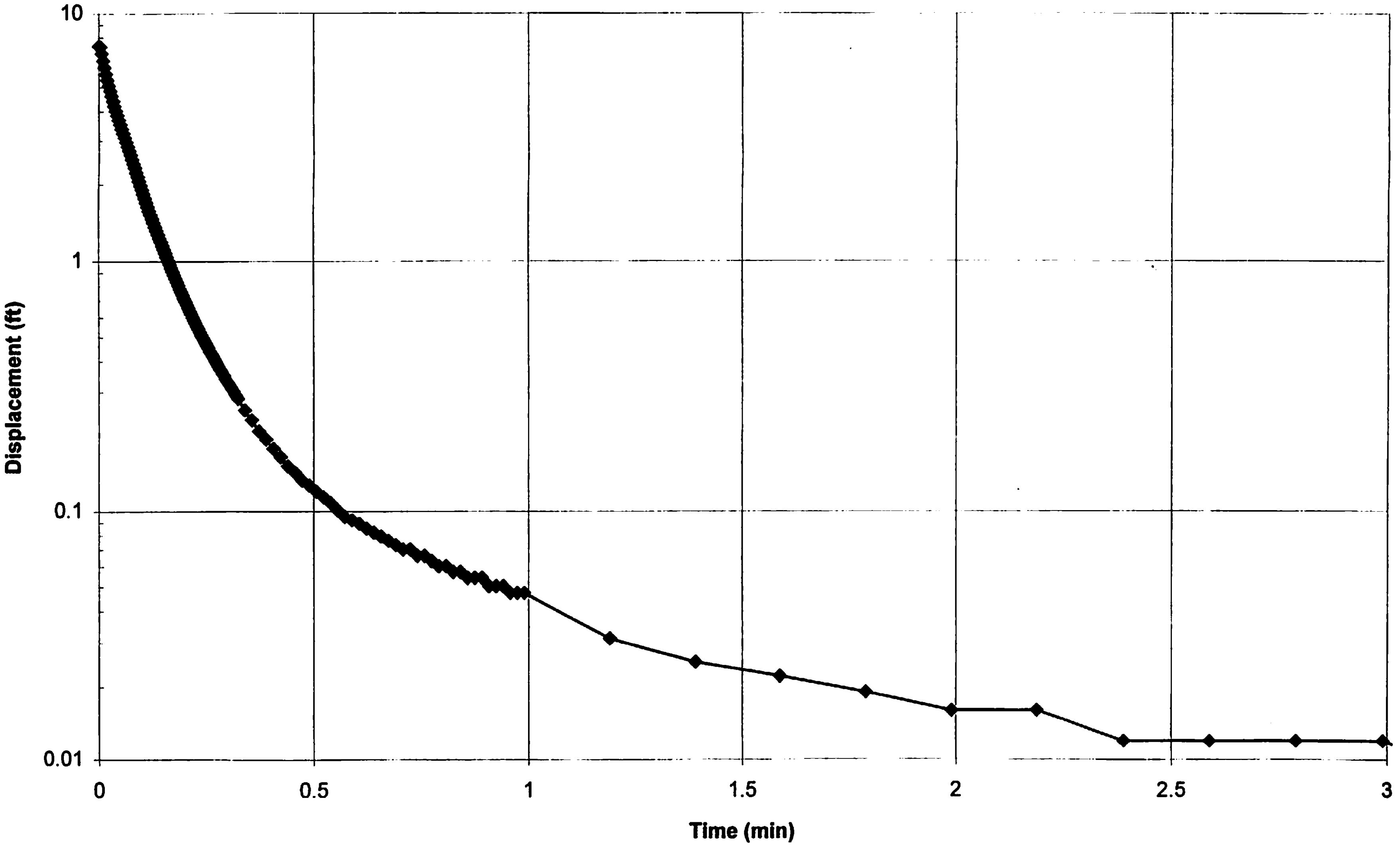
CW-1C Hvorslev Analysis

Well casing radius	r	0.0833	ft
Well bore radius	R	0.375	ft
Well screeen length	L	10	ft
Time to %37 of initial head change	To	0.213	min

Hydraulic Conductivity = r^2*LN(L/R)/(2*L*To)

=	**0.00534818**	**ft/min**
=	**7.70**	**ft/day**

CW-2B Slug Test Results
3/18/99



CW-2B Slug Test Analyses

CW-2B Bouwer-Rice Analysis

Casing Radius	Rc	0.0833	ft
Screen Length	L	10	ft
Borehole Radius	Rw	0.375	ft
Initial Drawdown	So	7.4	ft
Water Column Height	H	29.87	ft
Dimensionless constant	A	2.3	
Dimensionless constant	B	0.42	
Saturated Thickness	D	50	ft

Parameter used to determine the constants A and B
(from graph in Bouwer, 1976)

L/Rw	26.67

Ln Re/Rw = (1.1/ln(H/Rw) + (A+B*ln((D-H)/Rw))/(L/Rw))^-1

=	2.50

Point from time-drawdown curve used in solution:

Time	t	0.1	min
Drawdown	St	1.9	ft

Hydraulic Conductivity = (Rc^2*(Ln Re/Rw))/(2*L)*1/t*LN(So/St)

=	**0.01178529**	**ft/min**
=	**16.97**	**ft/day**

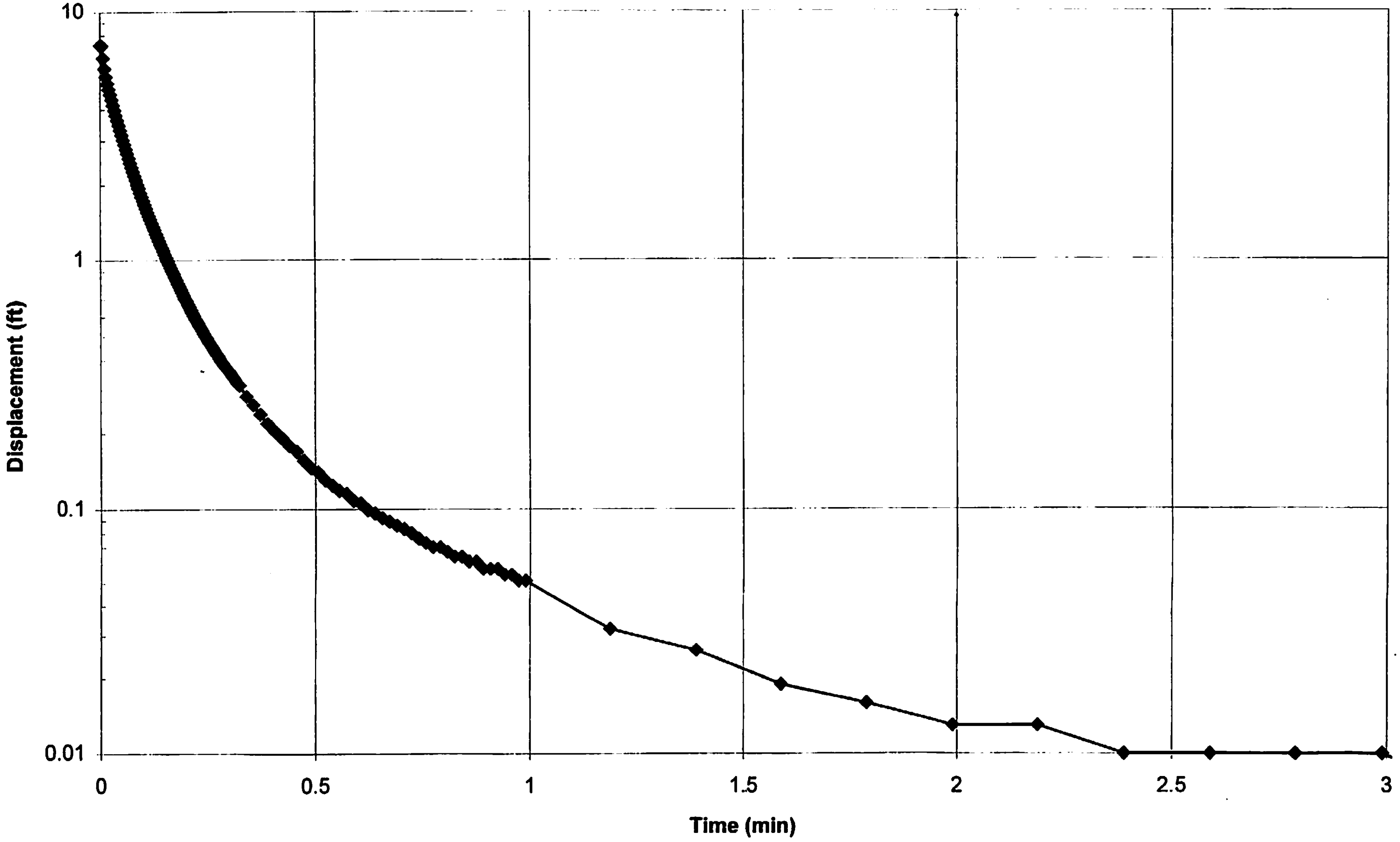
CW-2B Hvorslev Analysis

Well casing radius	r	0.0833	ft
Well bore radius	R	0.375	ft
Well screeen length	L	10	ft
Time to %37 of initial head change	To	0.07	min

Hydraulic Conductivity = r^2*LN(L/R)/(2*L*To)

=	**0.01627375**	**ft/min**
=	**23.43**	**ft/day**

CW-4B Slug Test Results
3/17/99



CW-4B Slug Test Analyses

CW-4B Bouwer-Rice Analysis

Casing Radius	Rc	0.0833	ft
Screen Length	L	10	ft
Borehole Radius	Rw	0.375	ft
Initial Drawdown	So	7.3	ft
Water Column Height	H	21.14	ft
Dimensionless constant	A	2.3	
Dimensionless constant	B	0.42	
Saturated Thickness	D	50	ft

Parameter used to determine the constants A and B
(from graph in Bouwer, 1976)

L/Rw	26.67

Ln Re/Rw = (1.1/ln(H/Rw) + (A+B*ln((D-H)/Rw))/(L/Rw))^-1

=	2.34

Point from time-drawdown curve used in solution:

Time	t	0.11	min
Drawdown	St	1.56	ft

Hydraulic Conductivity = (Rc^2*(Ln Re/Rw))/(2*L)*1/t*LN(So/St)

=	**0.01138613**	**ft/min**
=	**16.40**	**ft/day**

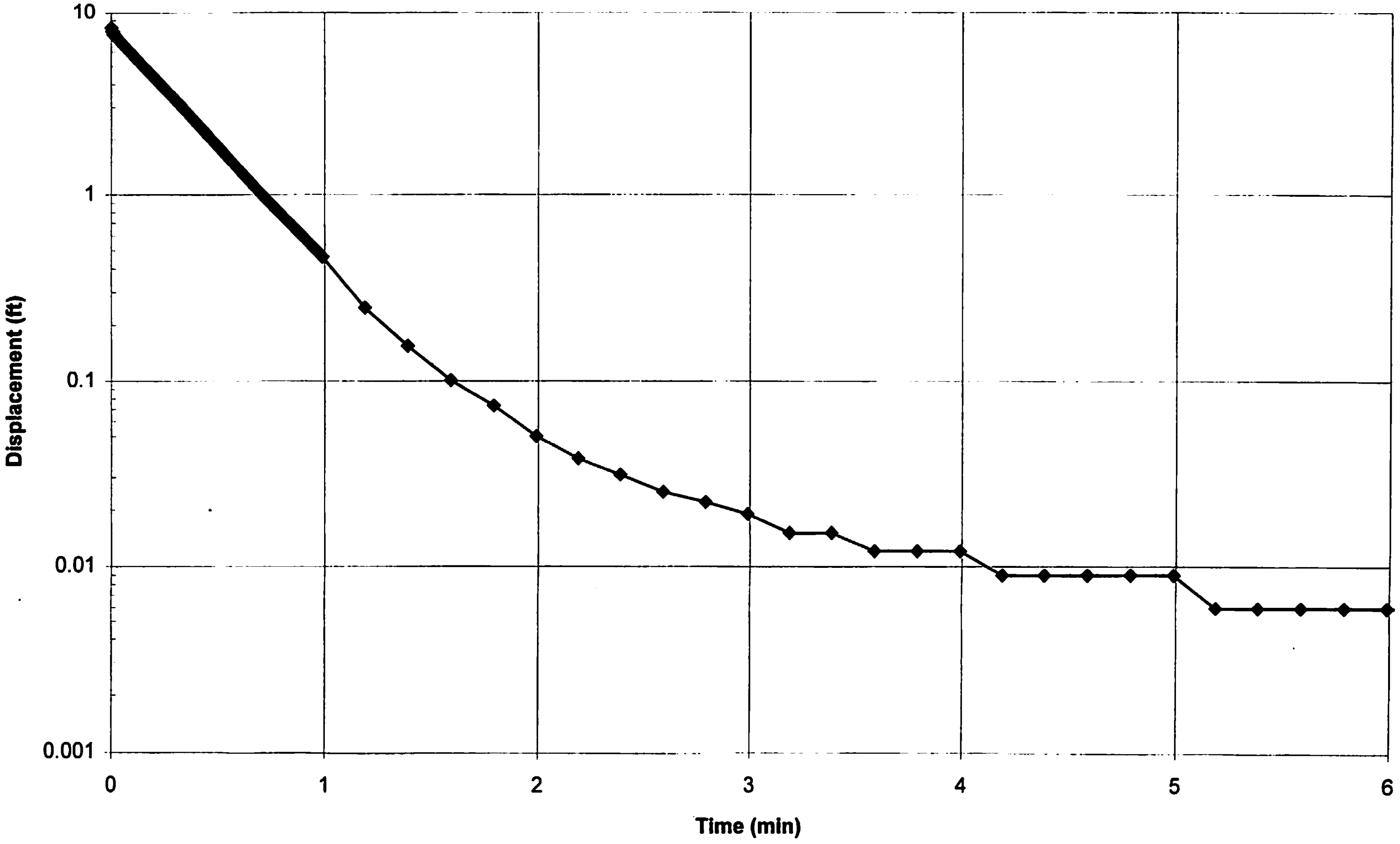
CW-4B Hvorslev Analysis

Well casing radius	r	0.0833	ft
Well bore radius	R	0.375	ft
Well screeen length	L	10	ft
Time to %37 of initial head change	To	0.063	min

Hydraulic Conductivity = r^2*LN(L/R)/(2*L*To)

=	**0.01808195**	**ft/min**
=	**26.04**	**ft/day**

CW-4C Slug Test Results
3/17/99



CW-4C Slug Test Analyses

CW-4C Bouwer-Rice Analysis

Casing Radius	Rc	0.0833	ft
Screen Length	L	10	ft
Borehole Radius	Rw	0.375	ft
Initial Drawdown	So	8.2	ft
Water Column Height	H	42.25	ft
Dimensionless constant	A	2.3	
Dimensionless constant	B	0.42	
Saturated Thickness	D	50	ft

Parameter used to determine the constants A and B
(from graph in Bouwer, 1976)

L/Rw	26.67

Ln Re/Rw = (1.1/ln(H/Rw) + (A+B*ln((D-H)/Rw))/(L/Rw))^-1

=	2.73

Point from time-drawdown curve used in solution:

Time	t	0.557	min
Drawdown	St	1.54	ft

Hydraulic Conductivity = (Rc^2*(Ln Re/Rw))/(2*L)*1/t*LN(So/St)

=	**0.00284004**	**ft/min**
=	**4.09**	**ft/day**

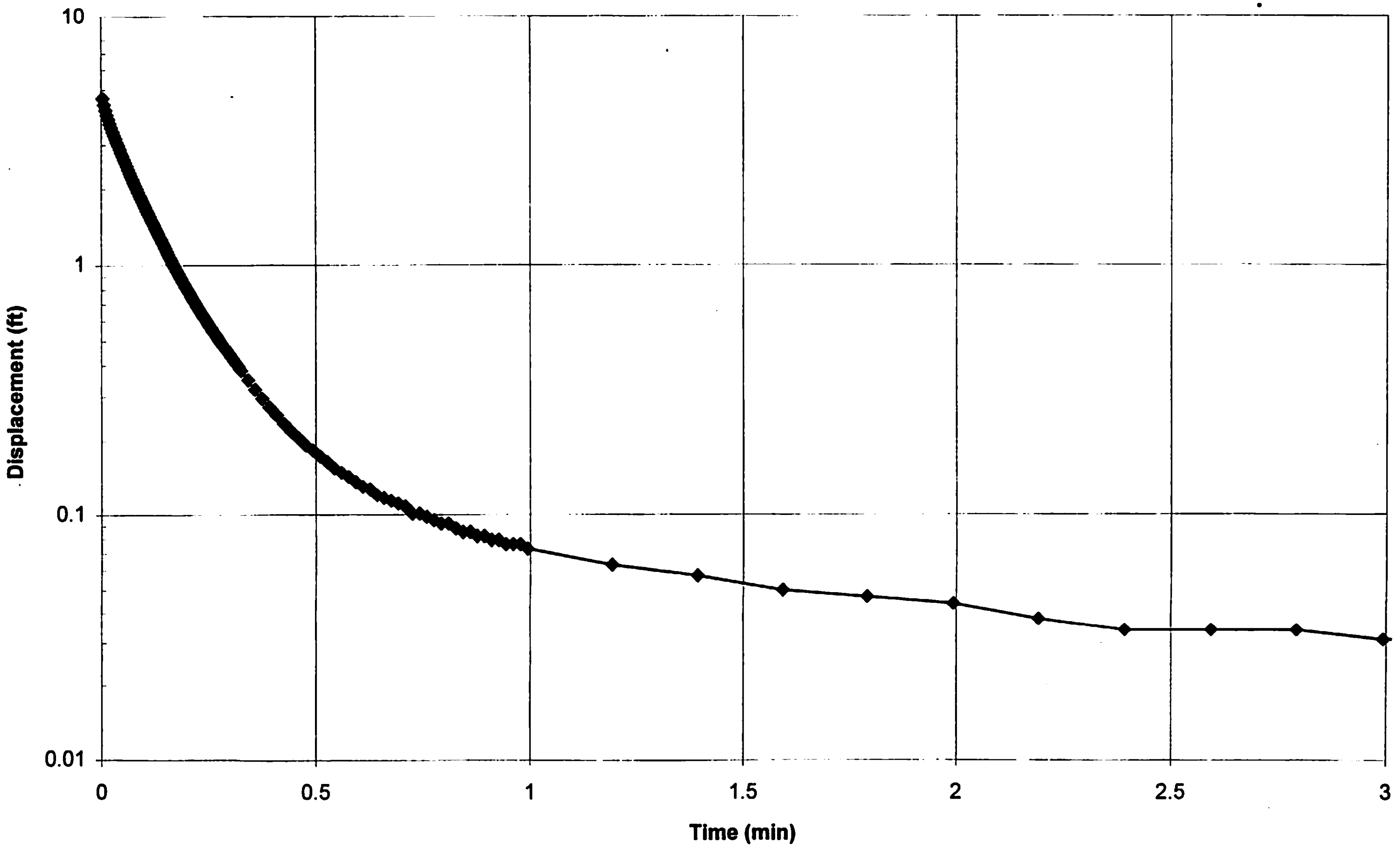
CW-4C Hvorslev Analysis

Well casing radius	r	0.0833	ft
Well bore radius	R	0.375	ft
Well screeen length	L	10	ft
Time to %37 of initial head change	To	0.33	min

Hydraulic Conductivity = r^2*LN(L/R)/(2*L*To)

=	**0.00345201**	**ft/min**
=	**4.97**	**ft/day**

CW-5B Slug Test Results
3/17/99



CW-5B Slug Test Analyses

CW-5B Bouwer-Rice Analysis

Casing Radius	Rc	0.0833	ft
Screen Length	L	10	ft
Borehole Radius	Rw	0.375	ft
Initial Drawdown	So	5.09	ft
Water Column Height	H	16.32	ft
Dimensionless constant	A	2.3	
Dimensionless constant	B	0.42	
Saturated Thickness	D	50	ft

Parameter used to determine the constants A and B
(from graph in Bouwer, 1976)

L/Rw	26.67

Ln Re/Rw = (1.1/ln(H/Rw) + (A+B*ln((D-H)/Rw))/(L/Rw))^-1

=	2.23

Point from time-drawdown curve used in solution:

Time	t	0.12	min
Drawdown	St	1.47	ft

Hydraulic Conductivity = (Rc^2*(Ln Re/Rw))/(2*L)*1/t*LN(So/St)

=	**0.00800441**	**ft/min**
=	**11.53**	**ft/day**

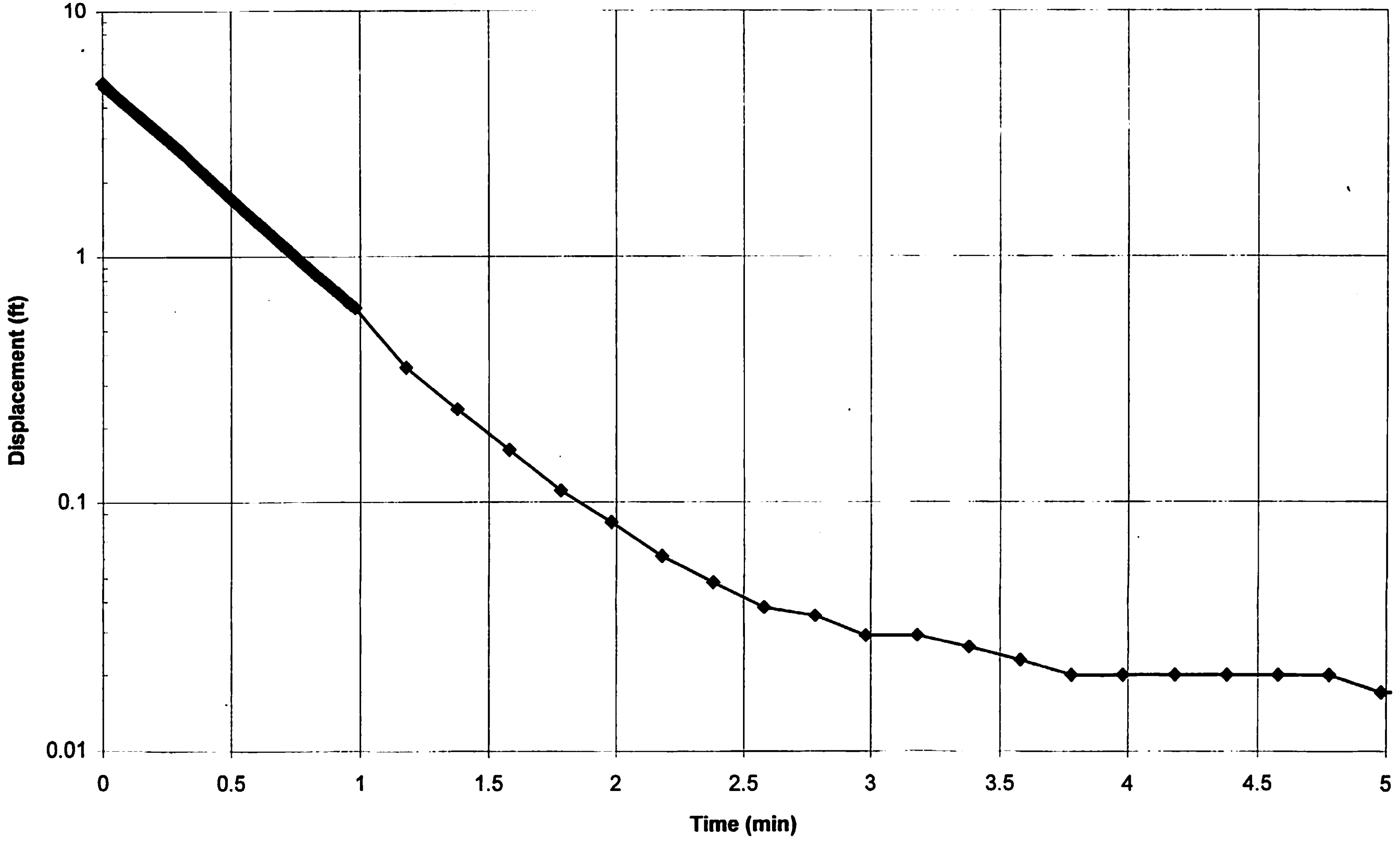
CW-5B Hvorslev Analysis

Well casing radius	r	0.0833	ft
Well bore radius	R	0.375	ft
Well screeen length	L	10	ft
Time to %37 of initial head change	To	0.102	min

Hydraulic Conductivity = r^2*LN(L/R)/(2*L*To)

=	**0.01116826**	**ft/min**
=	**16.08**	**ft/day**

MW-1B Slug Test Results
3/17/99



MW-1B Slug Test Analyses

MW-1B Bouwer-Rice Analysis

Casing Radius	Rc	0.125	ft
Screen Length	L	5	ft
Borehole Radius	Rw	0.375	ft
Initial Drawdown	So	4.8	ft
Water Column Height	H	16.32	ft
Dimensionless constant	A	2.3	
Dimensionless constant	B	0.42	
Saturated Thickness	D	50	ft

Parameter used to determine the constants A and B
(from graph in Bouwer, 1976)

L/Rw	13.33

Ln Re/Rw = (1.1/ln(H/Rw) + (A+B*ln((D-H)/Rw))/(L/Rw))^-1

=	1.65

Point from time-drawdown curve used in solution:

Time	t	0.88	min
Drawdown	St	0.76	ft

Hydraulic Conductivity = (Rc^2*(Ln Re/Rw))/(2*L)*1/t*LN(So/St)

=	**0.00540272**	**ft/min**
=	**7.78**	**ft/day**

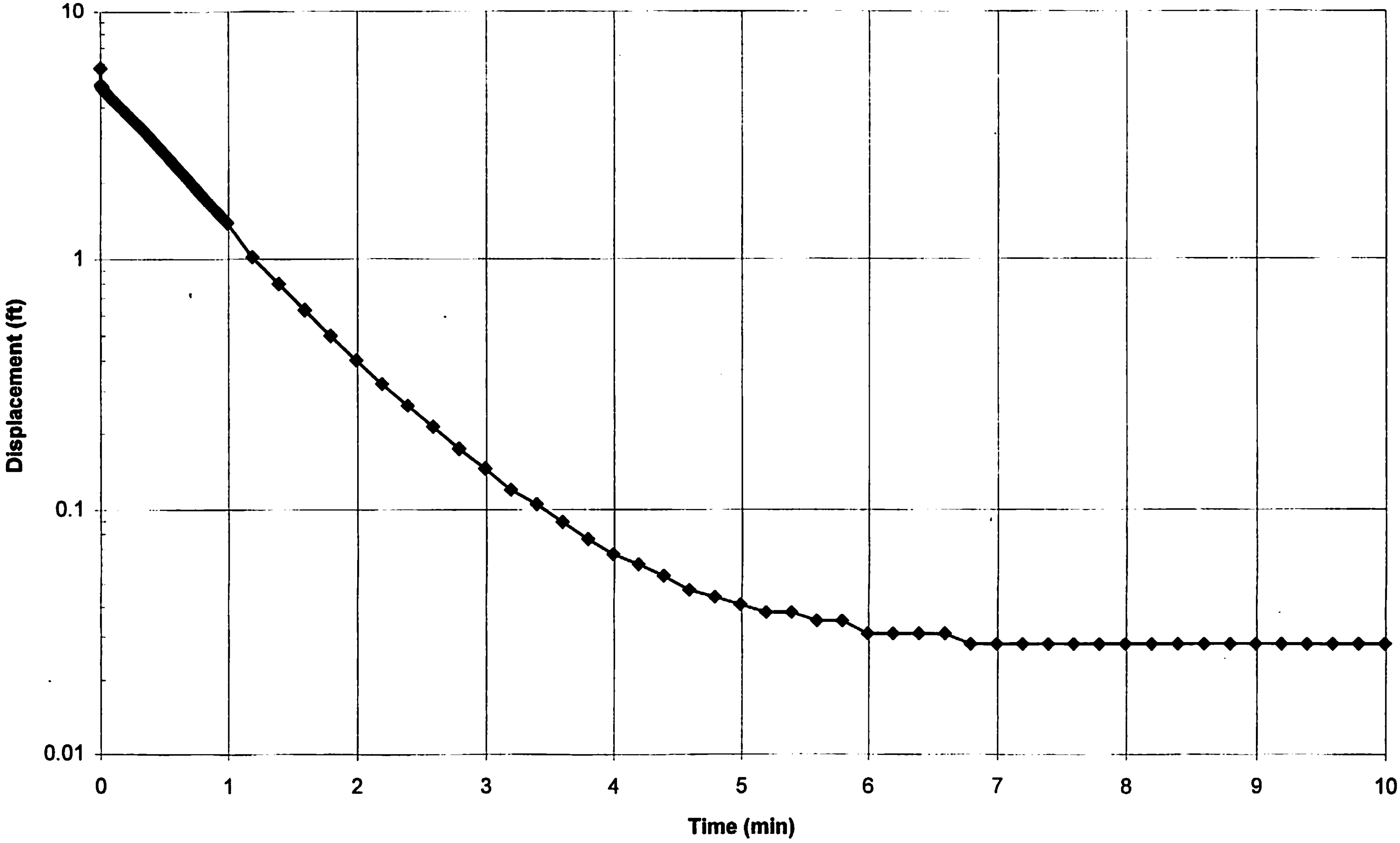
MW-1B Hvorslev Analysis

Well casing radius	r	0.125	ft
Well bore radius	R	0.375	ft
Well screeen length	L	5	ft
Time to %37 of initial head change	To	0.48	

Hydraulic Conductivity = r^2*LN(L/R)/(2*L*To)

=	**0.00843186**	**ft/min**
=	**12.14**	**ft/day**

MW-2B Slug Test Results
3/18/99



MW-2B Slug Test Analyses

MW-2B Bouwer-Rice Analysis

Casing Radius	Rc	0.125	ft
Screen Length	L	5	ft
Borehole Radius	Rw	0.375	ft
Initial Drawdown	So	5.77	ft
Water Column Height	H	25.62	ft
Dimensionless constant	A	2.3	
Dimensionless constant	B	0.42	
Saturated Thickness	D	50	ft

Parameter used to determine the constants A and B
(from graph in Bouwer, 1976)

L/Rw	13.33

Ln Re/Rw = (1.1/ln(H/Rw) + (A+B*ln((D-H)/Rw))/(L/Rw))^-1

=	1.77

Point from time-drawdown curve used in solution:

Time	t	0.94	min
Drawdown	St	1.47	ft

Hydraulic Conductivity = (Rc^2*(Ln Re/Rw))/(2*L)*1/t*LN(So/St)

=	**0.00402718**	**ft/min**
=	**5.80**	**ft/day**

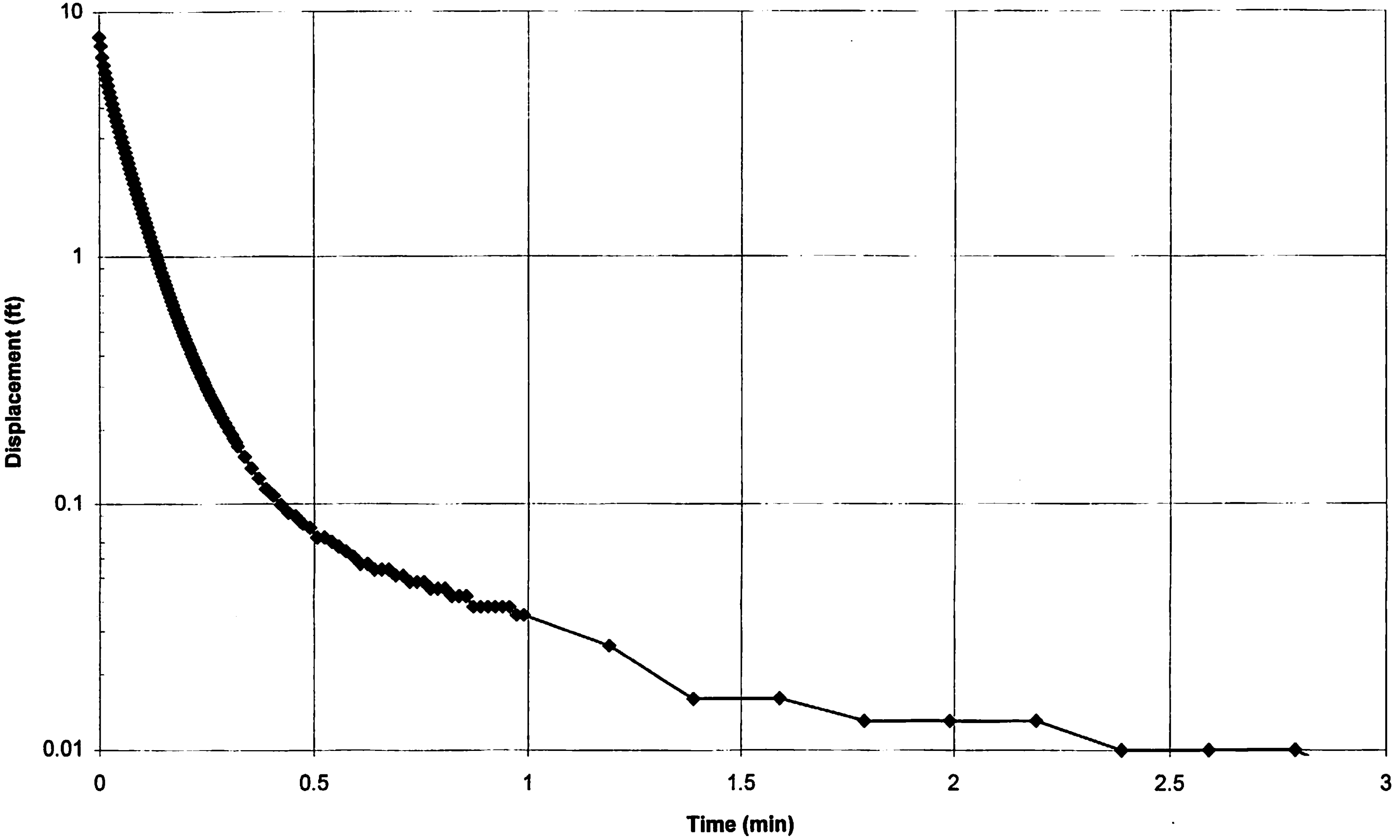
MW-2B Hvorslev Analysis

Well casing radius	r	0.125	ft
Well bore radius	R	0.375	ft
Well screeen length	L	5	ft
Time to %37 of initial head change	To	0.66	

Hydraulic Conductivity = r^2*LN(L/R)/(2*L*To)

=	**0.00613226**	**ft/min**
=	**8.83**	**ft/day**

WT-7B Slug Test Results
3/17/99



WT-7B Slug Test Analyses

WT-7B Bouwer-Rice Analysis

Casing Radius	Rc	0.0833	ft
Screen Length	L	10	ft
Borehole Radius	Rw	0.375	ft
Initial Drawdown	So	7.82	ft
Water Column Height	H	21.57	ft
Dimensionless constant	A	2.3	
Dimensionless constant	B	0.42	
Saturated Thickness	D	50	ft

Parameter used to determine the constants A and B
(from graph in Bouwer, 1976)

L/Rw	26.67

Ln Re/Rw = (1.1/ln(H/Rw) + (A+B*ln((D-H)/Rw))/(L/Rw))^-1

=	2.35

Point from time-drawdown curve used in solution:

Time	t	0.16	min
Drawdown	St	0.74	ft

Hydraulic Conductivity = (Rc^2*(Ln Re/Rw))/(2*L)*1/t*LN(So/St)

=	**0.01200482**	**ft/min**
=	**17.29**	**ft/day**

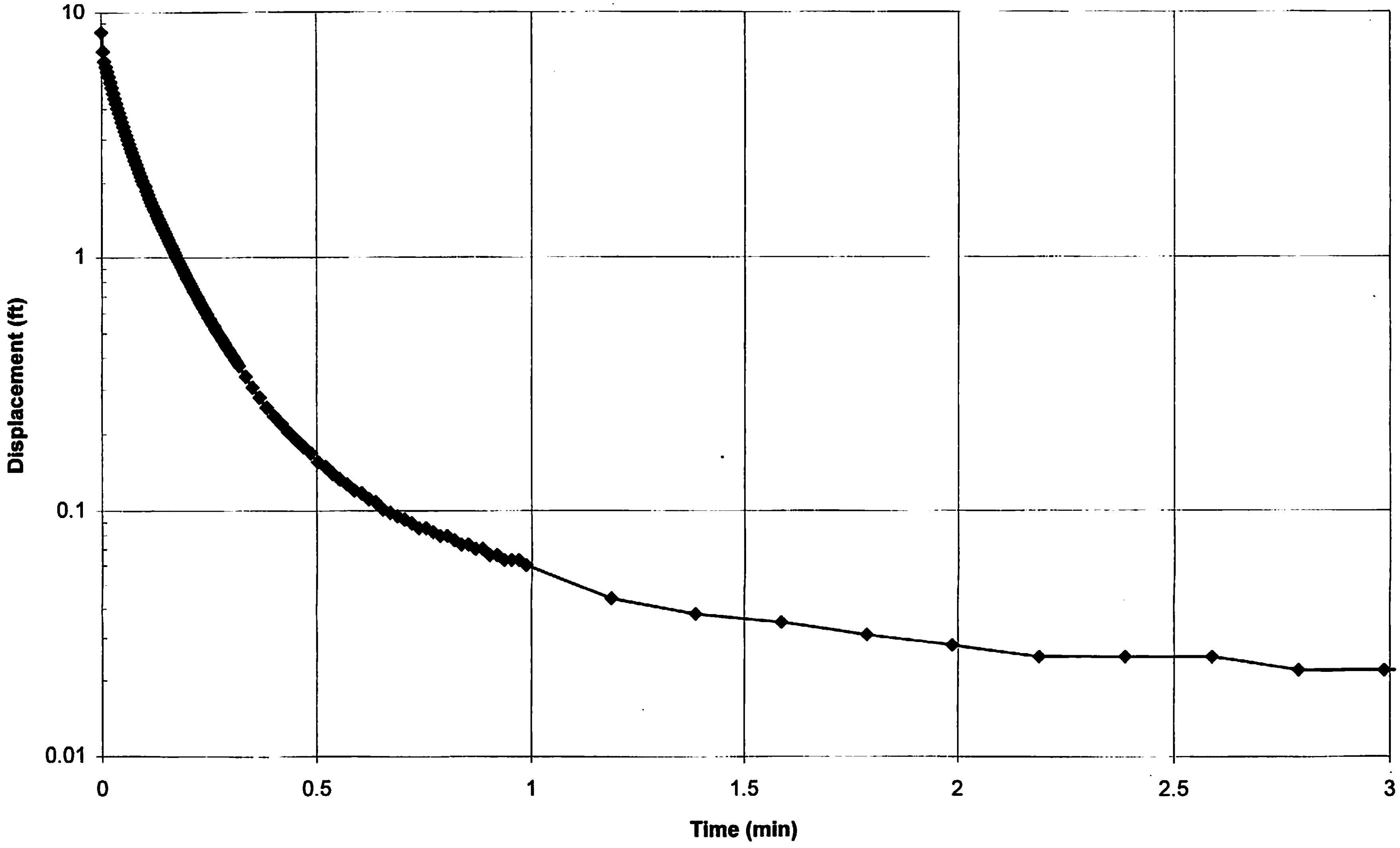
WT-7B Hvorslev Analysis

Well casing radius	r	0.0833	ft
Well bore radius	R	0.375	ft
Well screeen length	L	10	ft
Time to %37 of initial head change	To	0.054	min

Hydraulic Conductivity = r^2*LN(L/R)/(2*L*To)

=	**0.0210956**	**ft/min**
=	**30.38**	**ft/day**

WT-13B Slug Test Results
3/18/99



WT-13B Slug Test Analyses

WT-13B Bouwer-Rice Analysis

Casing Radius	Rc	0.0833	ft
Screen Length	L	10	ft
Borehole Radius	Rw	0.375	ft
Initial Drawdown	So	8.24	ft
Water Column Height	H	24.58	ft
Dimensionless constant	A	2.3	
Dimensionless constant	B	0.42	
Saturated Thickness	D	50	ft

Parameter used to determine the constants A and B
(from graph in Bouwer, 1976)

L/Rw	26.67

Ln Re/Rw = (1.1/ln(H/Rw) + (A+B*ln((D-H)/Rw))/(L/Rw))^-1

=	2.41

Point from time-drawdown curve used in solution:

Time	t	0.11	min
Drawdown	St	1.8	ft

Hydraulic Conductivity = (Rc^2*(Ln Re/Rw))/(2*L)*1/t*LN(So/St)

=	**0.01154352**	**ft/min**
=	**16.62**	**ft/day**

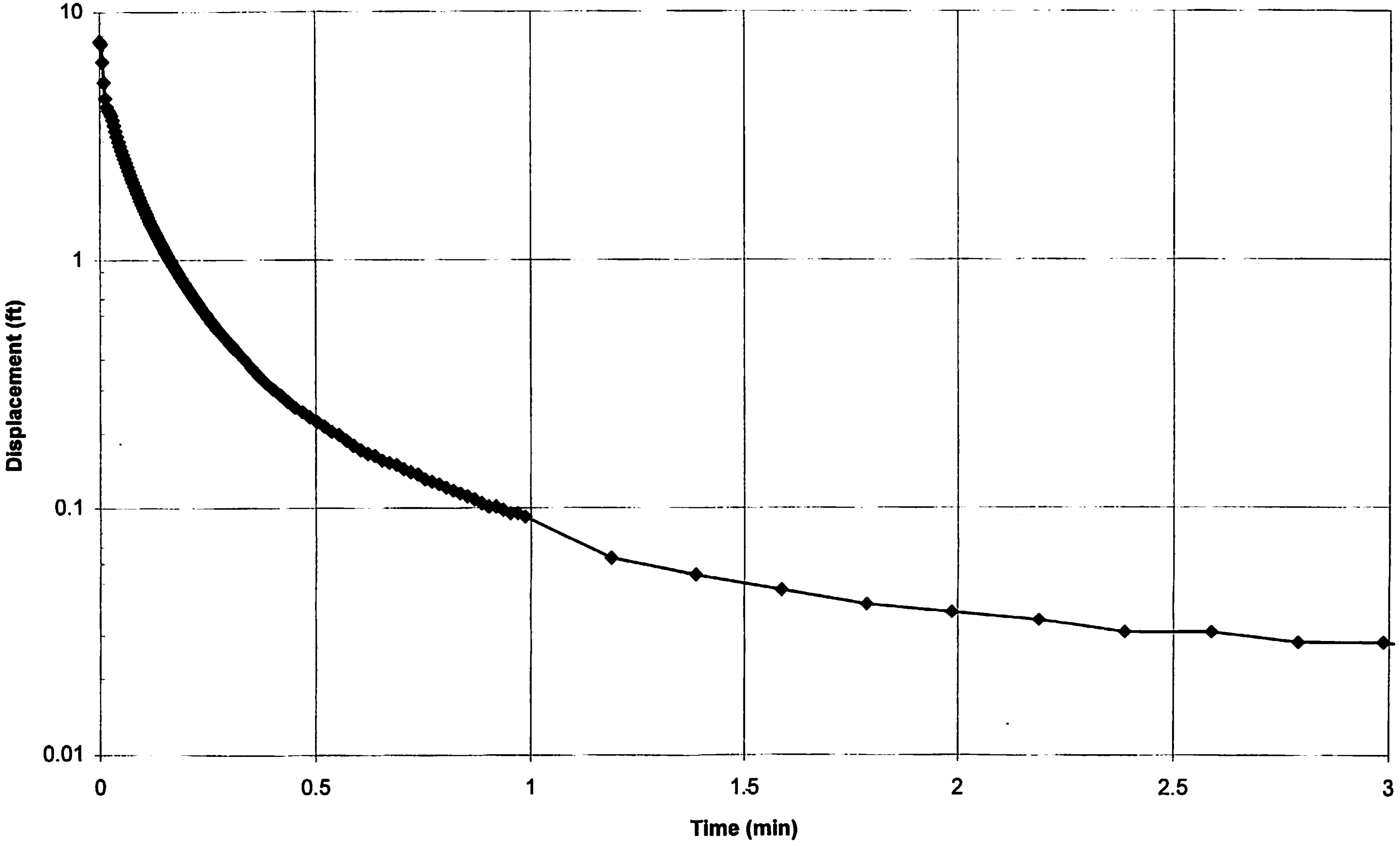
WT-13B Hvorslev Analysis

Well casing radius	r	0.0833	ft
Well bore radius	R	0.375	ft
Well screeen length	L	10	ft
Time to %37 of initial head change	To	0.058	min

Hydraulic Conductivity = r^2*LN(L/R)/(2*L*To)

=	**0.01964073**	**ft/min**
=	**28.28**	**ft/day**

WT-14B Slug Test Results
3/17/99



WT-14B Slug Test Analyses

WT-14B Bouwer-Rice Analysis

Casing Radius	Rc	0.0833	ft
Screen Length	L	10	ft
Borehole Radius	Rw	0.375	ft
Initial Drawdown	So	7.6	ft
Water Column Height	H	21.42	ft
Dimensionless constant	A	2.3	
Dimensionless constant	B	0.42	
Saturated Thickness	D	50	ft

Parameter used to determine the constants A and B
(from graph in Bouwer, 1976)

L/Rw	26.67

Ln Re/Rw = (1.1/ln(H/Rw) + (A+B*ln((D-H)/Rw))/(L/Rw))^-1

=	2.35

Point from time-drawdown curve used in solution:

Time	t	0.083	min
Drawdown	St	1.9	ft

Hydraulic Conductivity = (Rc^2*(Ln Re/Rw))/(2*L)*1/t*LN(So/St)

=	**0.01358896**	**ft/min**
=	**19.57**	**ft/day**

WT-14B Hvorslev Analysis

Well casing radius	r	0.0833	ft
Well bore radius	R	0.375	ft
Well screeen length	L	10	ft
Time to %37 of initial head change	To	0.048	min

Hydraulic Conductivity = r^2*LN(L/R)/(2*L*To)

=	**0.02373255**	**ft/min**
=	**34.17**	**ft/day**

Appendix F

Numerical Modeling of Groundwater Flow and Contaminant Transport

Appendix F

Numerical Modeling of Groundwater Flow and Contaminant Transport in the Waste Treatment Area GE Wilmington, NC Facility

December 22, 1999

Prepared by:
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F.1 Introduction

This document describes modeling activities to simulate groundwater flow and contaminant transport in the principal aquifer in the Waste Treatment (WT) area of the General Electric (GE) facility in Wilmington, North Carolina. This document is an appendix to the *Waste Treatment Area Investigation Report* (RTI Report No. 6448-020/001/01F, December 22, 1999), which presents results of an investigation of groundwater contamination identified in the WT Area.

The primary goal of the modeling effort was to understand the transport of the groundwater constituents of concern (nitrate and ammonia) and to predict their future migration patterns. Specific additional objectives of the modeling effort included the following:

- Refine the conceptual model describing the site hydrogeology and the transport of groundwater contaminants;

- Develop a quantitative, numerical groundwater flow model for the area that is consistent with the site conceptual model;

- Design the model to be flexible, allowing analysis of groundwater contamination within the WT area as well as potential future analysis of other areas of the active GE facility;

- Calibrate the flow model to measured site conditions;

- Develop models to simulate the fate and transport of the constituents of concern in groundwater;
- Calibrate the transport models to measured site conditions; and
- Use the calibrated numerical flow and transport models to simulate groundwater flow conditions at the site and to predict future plume migration patterns.

Certain figures and discussions found in the body of the *Area Investigation Report* are not reproduced in this appendix, but instead are referenced.

F.2 Background Information

The WT area is located in the west-central portion of the GE-Wilmington facility (*Area Investigation Report* Figure 1-1). Groundwater contamination was identified in the WT area of the GE-Wilmington site during a recent hydrogeologic investigation of the area (*Area Investigation Report* Figure 1-2). Levels of nitrate in the principal aquifer in this area exceed the North Carolina groundwater standard. Ammonia has also been identified in the principal aquifer, however there is no groundwater standard for this constituent. It is believed that a slow leak from one or both of the two nitrate-liquid basins at the north end of the WT Facility resulted in the groundwater contamination. *Area Investigation Report* Figures 4-4 and 4-6 show the current distribution of nitrate and ammonia in the principal aquifer, respectively. The main body of the *Area Investigation Report* provides a comprehensive summary of results of the assessment activities conducted in the WT site area.

F.3 Conceptual Model

This section describes the conceptual model — the current qualitative understanding of the geology and hydrogeology of the site and region and its relationship to the WT area contamination. The conceptual model is the basis for the development of the quantitative, numerical flow and transport model.

F.3.1 Location and Topography

The GE facility is located in northwest New Hanover County in the North Carolina Coastal Plain. *Area Investigation Report* Figure 1-1 shows the USGS topographic map for the area (the Castle Hayne, NC quadrangle). Elevations in this region generally range between 0 and 50 feet above mean sea level (msl). Based on review of the topographic map, the Cape Fear River, streams (e.g., Ness Creek and Prince George Creek), and the low-lying swampy areas constitute major hydrogeologic boundaries for the groundwater flow system.

F.3.2 Hydrogeologic Units

The hydrogeologic units of concern in the area include the surficial aquifer and the principal aquifer. *Area Investigation Report* Figures 3-2 and 3-3 present hydrogeologic cross sections indicating the positions of these units in the WT area.

The surficial aquifer includes undifferentiated, highly stratified deposits generally between 20 and 50 ft msl. These sediments typically include terraced and barrier beach deposits, fossil sand dunes, and stream channel deposits. The soils vary from medium to fine-grained sands to silts and clays. The more permeable surficial deposits form the surficial aquifer. This aquifer is recharged directly by rainfall, and the water table is generally near the land surface (approximately from 0 to 10 feet below ground). Discharge of the aquifer is into streams, drainage canals, and the low-lying swampy areas surrounding most of the upland areas. In addition, the surficial aquifer recharges water into the underlying principal aquifer in some areas.

Relatively less permeable silty and clayey deposits underlie most of the surficial aquifer, forming the semiconfining layer. The semiconfining layer is a highly heterogeneous, interbedded unit that is not present in all areas. The semiconfining layer appears to pinch out to the west and northwest of the WT area. For example, site investigation indicated that there is no semiconfining layer in northwest site area of the GE property (RTI, 1998).

The principal aquifer lies below the surficial aquifer and the semiconfining layer. The principal aquifer consists of the upper zones of the Peedee Formation, a Cretaceous-age deposit including greenish-gray to dark-gray silt and sand interbedded with semi-consolidated calcareous sandstone and limestone. The upper portion of the principal aquifer is the most permeable and contains more sand than the lower zones. The unit dips to the southeast as shown in *Area Investigation Report* Figure 3-1. (The principal aquifer coincides with the "Sandstone Aquifer" as labeled in this figure.)

According to Bain (1970), there is a regional geologic contact dividing the portion of New Hanover County where the GE site is located, as shown in *Area Investigation Report* Figure 1-1. To the east of this contact, the principal aquifer corresponds to the more permeable, upper sandy portion of the Peedee Formation, identified as "Sandstone Aquifer" on the cross section shown in *Area Investigation Report* Figure 3-1. To the west of this geologic contact, the Peedee Formation pinches out and the sediment has an increasing silt and clay component and lower permeability. The semiconfining layer also pinches out to the west of this contact, and the principal and surficial aquifers thus essentially become the same hydrogeologic unit with similar properties. Because there is no semiconfining unit, the aquifer to the west and northwest of the geologic contact is a water-table (unconfined) aquifer rather than a confined aquifer. Because the area west of this contact has not been investigated thoroughly, this conclusion is inferred from the hydrogeologic study by Bain (1970) and limited site-specific information. However, the pattern has been confirmed for the northwest site area (RTI, 1998).

F.3.3 Principal Aquifer Groundwater Flow

Because the focus of the modeling effort is on the principal aquifer, surficial aquifer groundwater flow patterns will not be discussed here. *Area Investigation Report* Section 3.2.1 discusses groundwater flow in the surficial aquifer.

Plate F-1 shows principal-aquifer water levels collected throughout the GE site in June 1999. As this plate indicates, groundwater flows from upland areas toward the surrounding hydrogeologic boundaries, including streams, the Northeast Cape Fear River, and the low-lying swampy area that surrounds much of the region. The primary input of groundwater to the principal-aquifer system is recharge from leakage through the overlying semiconfining layer and from direct seepage of rainwater in areas where the semiconfining layer is absent (e.g., west and northwest of the geologic contact in *Area Investigation*

Report Figure 1-1). In general, groundwater enters the system through recharge and flows outward toward the hydrogeologic boundaries.

Principal-aquifer water elevations in the WT area have fluctuated over a range of approximately 8 to 14 feet between October 1993 and September 1999 (Figure F-1). Even though the water levels have varied over this range, the resulting groundwater flow patterns have generally followed similar patterns throughout this period, as is evident in comparing the water-level contours in Figure F-2 from October 1999 (with relatively higher water elevations) and June 1997 (with relatively lower water elevations). The water-level contours in Figure F-2 were generated automatically using a kriging interpolation method. Therefore, in some areas the patterns are somewhat inconsistent with those shown in Plate F-1, which was produced manually using professional hydrogeologic insight. Nevertheless, the contours in Figure F-2 provide a useful comparison of water-level patterns over time.

F.3.4 Hydrogeologic Parameters

This section describes general information about hydrogeologic parameters developed from site-specific data and analyses as well as literature research. Specific parameter estimates used in the model are presented in Sections F.4.3 and F.5.3.

F.3.4.1 Hydraulic Conductivity. Estimates for hydraulic conductivity were developed using existing knowledge of the GE site (including slug tests, grain size analyses, and pumping tests performed in other areas of the site) as well as measurements performed within the WT area. The hydraulic conductivity measurement in the WT area involved pneumatic slug testing of 12 wells screened in the principal aquifer. *Area Investigation Report* Appendix E describes the pneumatic slug-test method and the testing results in detail. *Area Investigation Report* Table 3-1 presents a summary of the slug-testing results in the WT area. As this table indicates, the hydraulic-conductivity estimates vary from 4 to 34 ft/day, and the overall geometric means calculated using two analysis methods are 11 and 17 ft/day. Also, it is apparent that the hydraulic conductivity generally decreases with depth in the principal aquifer, as is expected from the geology of the Peedee Formation. Using two analysis methods, the geometric-mean hydraulic-conductivity value for the deeper wells (those screened completely below mean sea level) varies from 6 to 8 ft/day, while the geometric mean for the shallower wells varies from 15 to 24 ft/day.

Hydraulic conductivity results from other areas of the GE site indicate that there is a general increasing trend in hydraulic conductivity from the west to east across the facility. For example, two analysis procedures applied to slug-test data generated in the northwest area of the GE facility indicate geometric-mean hydraulic-conductivity values of 1 and 3 ft/day (RTI, 1998; RTI, 1999a). In contrast, pumping tests in pumping well WW-9A (approximately 3,000 feet east-northeast of the WT area) indicate a hydraulic conductivity in the 40 ft/day range (RTI, 1996). The hydraulic conductivity measurements for the WT area (*Area Investigation Report* Table 3-1) fall between the ranges measured for the western and the eastern areas of the GE facility. This observation agrees with the assessment by Bain (1970) that there is a regional geologic contact dividing the portion of New Hanover County where the GE site is located, as shown in *Area Investigation Report* Figure 1-1. To the east of this contact, the principal aquifer corresponds to the more permeable, upper sandy portion of the Peedee Formation, identified as "Sandstone Aquifer" on the cross section shown in *Area Investigation Report* Figure 3-1. The conductivity is correspondingly in the upper range of measured values for the site. To the west of this geologic contact, the conductivity decreases as the upper sandy portion of the Peedee Formation pinches out and the sediment has an increasing silt and clay component.

The flow modeling includes only steady-state simulations and does not have a temporal component. Therefore, aquifer storage properties are not required.

F.3.4.2 Sorption, Porosity, and Bulk Density. As described in *Area Investigation Report* Section 5.1.2, nitrate is a non-sorbing anion and typically will not be attenuated through sorption. However, ammonia compounds typically will sorb under pH conditions at the site, under which ammonia is primarily in the form of the ammonium ion (NH_4^+). As described in *Area Investigation Report* Section 5.1.3, ammonium will often readily attenuate due to sorption processes, including cation exchange. Two parameters that describe the degree to which sorption processes occur are the distribution coefficient (K_d) and the retardation factor. Drever (1988) reports that the measured K_d in some natural sandstone aquifers ranged from 2 to 10 liters per kilogram, which translates to a range of approximately 16 to 80 for the retardation factor, assuming a porosity of 0.3 and a bulk density of 1.56 g/cm^3. These values for the porosity and bulk density are typical for fine to medium sandy soils (Brady, 1990). A retardation factor between 16 and 80 indicates that the constituent will travel 16 to 80 times slower than the groundwater.

F.3.4.3 Dispersion. Dispersivity estimates can be developed using the convention that the longitudinal dispersivity tends to be between one and ten percent of the plume length scale, and the transverse dispersivity tends to be approximately one order of magnitude lower than the longitudinal dispersivity. Using this convention and given the length of the plume (roughly 850 ft), the longitudinal dispersivity would range approximately between 8.5 and 85 ft, and the transverse dispersivity would be approximately between 0.85 and 8.5 ft.

F.3.4.4 Aqueous Nitrogen Reactions. *Area Investigation Report* Section 5 presents site-specific evidence of potential reactions that could transform nitrate and ammonium in the principal aquifer. The information collectively suggests that the nitrate plume is attenuating. Further, the most likely attenuation mechanism appears to be denitrification, whereby nitrate is converted to nitrogen gas. However, due to the fact that data are available only since 1998, the degree to which natural attenuation is limiting the nitrate contamination is uncertain. Nevertheless, reported half lives for field-scale denitrification have ranged from one month to two years, as described in *Area Investigation Report* Section 5.1.1.1.

F.3.5 Hydrogeologic Boundaries

The principal hydrogeologic boundaries for the system, as described in Section F.3.1, are recharge, discharge to streams, discharge to the low-lying swampy area, discharge to the Northeast Cape Fear River, and flow into and out of the effluent channel.

F.3.5.1 Recharge. Flow from the surficial aquifer to the principal aquifer depends on the hydraulic gradient between these aquifers and the thickness and vertical hydraulic conductivity of the semiconfining layer. Because the semiconfining layer is a highly heterogeneous, interbedded geologic unit, the amount of leakage through this layer can vary greatly in different areas. Figure F-3 shows the difference in the groundwater elevation between the surficial and principal aquifers based on data collected in June 1999 (principal-aquifer elevations subtracted from surficial-aquifer elevations). As this figure indicates, the surficial-aquifer levels are higher than the principal-aquifer levels in most areas, with the difference varying mostly between 3 and 40 feet. The greatest differences are in the vicinity of the pumping wells, which have significantly lowered the water levels in the principal aquifer. For any given conductivity and thickness of the semiconfining layer, recharge to the principal aquifer would increase as the head difference increases. Accordingly, the recharge rate can be estimated using the following form of Darcy's law:

$$\text{Recharge Rate} = K_v\,(h_{surf} - h_{princ})/L_{sl}$$

where K_v is the vertical hydraulic conductivity of the semiconfining layer, h_{surf} is the head in the surficial aquifer, h_{princ} is the head in the principal aquifer, and L_{sl} is the semiconfining layer thickness. Combining the head difference in Figure F-3 with the estimated thickness of the semiconfining layer (Figure F-4) and an estimated vertical hydraulic conductivity of the semiconfining layer of 0.001 ft/day, the recharge to the principal aquifer is estimated to range approximately from 3 to 26 inches per year.

Although this analysis gives a reasonable range for the recharge values, it is important to understand that small head differences between the principal and surficial aquifers could also indicate relatively effective communication between these units (or even the absence of the semiconfining layer), whereby head gradients readily dissipate between the aquifers. In such areas, the above estimates of recharge would likely be inaccurate, because a greater volume of groundwater could flow between the aquifers without a large head differential. One example is the northwest site area where the semiconfining layer is absent. Modeling of the northwest site area (RTI, 1999a) indicated a recharge rate of 11.6 inches per year, which is about 23 percent of the annual average rainfall in the Wilmington area of 50 inches per year.

The recharge values developed using the above methodology were applied as initial estimates for the modeling. However, considering the uncertainty of recharge estimates in the principal-aquifer system, the recharge was varied manually during flow-model calibration to minimize the differences between measured and simulated groundwater elevations, as described in Section F.4.5.3.

F.3.5.2 Surface-Water Interaction. Groundwater in the principal aquifer does not interact significantly with most surface-water features (e.g., streams, swampy area, and effluent channel) at higher elevations, because the stream beds are separated from the aquifer by the less permeable semiconfining layer. However, at lower elevations, the streams have incised through the semiconfining layer and are in direct connection with the principal aquifer. Therefore, the principal aquifer groundwater elevations typically are influenced by surface water only at lower elevations. Due to historical dredging of the original streambed, the effluent channel (shown in *Area Investigation Report* Figure 1-2) is the only known exception to this pattern. Some of the original dredged depth of the effluent channel streambed has been filled in with relatively more permeable sandy, alluvial sediments, and the semiconfining layer is assessed to be thin or absent along much of the dredged length of the effluent channel. Therefore, groundwater can flow more readily between the principal aquifer and the effluent channel in the dredged areas. As discussed in *Area Investigation Report* Section 3.2.3.1, the effluent channel is understood in general to be a losing stream east (upstream) of the WT investigation area and a gaining stream west (downstream) of the WT investigation area.

The low-lying swampy area surrounding much of the region (*Area Investigation Report* Figure 1-1) constitutes an additional major hydrogeologic boundary. Very strong upward vertical gradients in the swampy area (on the order of 0.15 in the northwest site area) indicate that this area is a major groundwater discharge boundary (RTI, 1998).

F.3.5.3 Groundwater Pumping. GE maintains a system of 18 active pumping wells across the facility (shown in Figure F-5) that provide water for plant processes and eliminate the potential for offsite migration of groundwater contamination. The total runtime and a measured instantaneous flow rate are collected monthly for each well. These data were time averaged to estimate the overall total monthly flow rate using the following formula:

$$Q_{total} = \frac{(Q_{inst}\, t_{runtime})}{t_{total}}$$

where Q_{total} is the time-averaged flow rate, Q_{inst} is the instantaneous flow rate, $t_{runtime}$ is the pump runtime, and t_{total} is the total time.

Figure F-5 shows the resulting time-averaged flow rates for the site pumping wells during the June 1999 time period. Figure F-6 shows the variation in the flow rate over time for a representative set of pumping wells. The pumping rates generally remain within fairly consistent ranges, although maintenance activities or periods of higher water demand require the pumping rates to be occasionally adjusted, thus impacting the average flow rates. Also, the pumping rates are modified occasionally to control the migration of contaminant plumes across the site.

F.4 Flow-Model Development and Results

This section describes the development of the groundwater flow model, including the code, the finite-difference grid, input parameters, and boundary conditions.

F.4.1 Code Description

The flow model code, MODFLOW, is a three-dimensional, block-centered finite-difference numerical model that was developed by the USGS (McDonald and Harbaugh, 1988). The model is widely tested and applied. MODFLOW can solve for both steady-state and transient conditions. Simulation output includes water balances and heads for each time step and layer. MODFLOW can handle multiple boundary conditions, including specified head, specified flux, and various mixed-type boundaries. The model can also simulate multiple hydraulic sources and sinks, including recharge, rivers, drains, lakes, pumping wells, injection wells, and evapotranspiration. The MODFLOW pre- and post-processor Visual MODFLOW was used to prepare input files and to analyze the results.

F.4.2 Finite-Difference Grid

The model domain includes the area of concern (the WT area) and extends outside of this area to include the relevant regional hydrogeologic boundaries for the principal aquifer (Figure F-7). The boundaries include the low-lying swampy area to the northwest and southwest, the Northeast Cape Fear River to the west, and Prince George Creek to the northwest. The eastern lateral edge of the model is estimated to be perpendicular to the groundwater flow in this area. Because groundwater does not flow perpendicular to flow paths, this eastern edge of the model is established as a no-flow boundary for the flow system.

The spacing of the finite-difference rows and columns is shown in Figure F-8. Relatively fine grid spacing is often required for accurate transport modeling. Therefore, the established grid spacing is 50 ft in the area encompassing measured groundwater impacts at the GE site. In order to decrease computer memory and processing requirements, the grid spacing was increased outside of this area. A coarser grid is adequate in these regions, because the contaminant plumes do not extend to these areas, making transport modeling unnecessary. With the spacing described above, the finite-difference grid contains a total of 183 columns and 129 rows.

The design of the model top elevation depends on the location within the model domain. To the east of the geologic contact (*Area Investigation Report* Figure 1-1), the model top corresponds to the top surface of the principal aquifer (the bottom of the semiconfining layer). This unit dips to the southeast as shown in the cross section in *Area Investigation Report* Figure 3-1 (the principal aquifer corresponds to the "Sandstone Aquifer" identified in this figure). To the west of the geologic contact, the top of the model corresponds to the land surface, because the semiconfining unit is absent in this area, and the aquifer is a water-table aquifer. Note that for a simulated water-table aquifer, the top surface is typically the land surface, even though the water level is usually below this level and is determined as part of the simulation. In contrast, for a simulated confined aquifer, the top surface represents the actual top of the aquifer.

Within the GE property, the model top surface was estimated by interpolating data from well and boring logs across the site. Outside of the GE property and to the west of the geologic contact, the top of the model was set to the ground surface elevation based on USGS digital elevation model (DEM) data, which provide surface elevations across the region. Outside of the GE property and to the east of the geologic contact, the top of the model dips to the east following information from Bain (1970) shown in Figure F-9. Figure F-10 shows the final model top elevation distribution.

The model includes two layers. To the east of the geologic contact, the uppermost layer corresponds to the more permeable and more sandy section of the principal aquifer. In this region, this model layer extends 20 feet below the top of the principal aquifer. Bain (1970) estimates that the sandstone aquifer averages 35 feet thick. However, site-specific evidence collected at the GE facility indicates that the conductivity decreases significantly at depths shallower than reported by Bain, and thus a thickness of 20 feet was selected for the upper model layer to the east of the geologic contact. In addition, the contamination is generally confined to the upper 20 feet of the principal aquifer. The lower model layer corresponds to deeper sediment of the Peedee Formation that contains greater levels of silt and clay and has a lower permeability. To the east of the geologic contact, this lower model layer extends 50 feet below the upper model layer. This lower model layer is included, because significant volumes of groundwater within the modeled regional hydrogeologic system flow within this deeper zone, and the deeper portion of the principal aquifer does, therefore, impact the flow system. However, because the contamination is located primarily in the upper portion of the principal aquifer, the lower layer is relatively insignificant for transport modeling.

To the west of the geologic contact, the semiconfining unit is absent, and the upper and lower model layers have similar properties. In this region, the model bottom elevation was set to a constant elevation of -50 ft msl. Figure F-11 shows the final model bottom elevation distribution.

The thickness of the lower model layer is somewhat arbitrary, however the results in the upper model layer are relatively insensitive to this specification. With a thicker lower layer, similar results would be achieved by increasing the recharge, thus providing more flow to a thicker lower model layer. Correspondingly with a thinner lower model layer, similar results would be achieved by decreasing the recharge. Given that the recharge estimates resulting from the calibration effort appear reasonable (see Section F.4.5.3 below), the selected thickness of the lower layer is sufficiently accurate to model the flow system of concern.

With two layers, 183 columns, and 129 rows, the model grid contains a total of 47,213 cells.

F.4.3 Input Parameters

Section F.3.4 provided general information about model input parameters that was based on site-specific investigation and literature research. Table F-1 provides a comprehensive list of the flow model input parameters, specific parameter values used in the flow model, and a summary of the basis for the parameter estimates.

F.4.4 Boundary Conditions

As discussed in Section F.3.3, groundwater generally flows from upland recharge areas outward into discharge areas, including the swampy area, the Northeast Cape Fear River, and streams. This section discusses the model treatment of each of these discharge features and the additional boundaries within the flow-model domain. Figure F-7 shows the location of each of the model boundaries.

F.4.4.1 Recharge. Recharge is represented through a recharge boundary in MODFLOW, which delivers a specified flux of groundwater to the top of the model. This recharge boundary extends throughout the model domain. An initial estimate of the recharge was developed in Section F.3.5.1. However, considering the uncertainty of recharge estimates for this groundwater system, recharge was varied manually during calibration, as described below in Section F.4.5.3.

F.4.4.2 Stream Drain Boundaries. As discussed in Section F.3.5.2, groundwater from the principal aquifer discharges to streams only at lower elevations, where the streams have incised through the semiconfining layer. At upper elevations, the semiconfining layer prevents significant interaction between streams and the principal aquifer. In this situation, streams can be represented in MODFLOW using drain boundaries. A drain boundary only allows groundwater to leave the system through discharge to the boundary. The rate of flux out of the system through a drain depends on the specified elevation of the drain and the surrounding groundwater piezometric head. If the piezometric head falls below the drain elevation, the boundary becomes inactive, and groundwater does not enter (or leave) the groundwater system through the drain. Likewise, the flux of water leaving the groundwater system increases as the piezometric head increases relative to the drain elevation. Drain elevations were set based on the estimated average elevation of water in the stream beds, which was derived through review of the topographic map.

The flux of groundwater out of a drain boundary is also controlled by a conductance parameter which is linearly proportional to the flux. For the drain boundaries, the conductance is set to a high enough value (2,000 ft^2/day) to allow the maximum amount of flow out of the system. With a high conductance value, the drains are essentially specified head boundaries with the important difference that they only allow flow out of the groundwater system and are inactive if the piezometric head is below the drain elevation.

As Figure F-7 shows, drain boundaries are specified for three streams to the south and southwest of the GE property and one stream to the north.

F.4.4.3 Effluent Channel River Boundary. The effluent channel is modeled as a river boundary. This boundary is similar to a drain boundary, as described in Section F.4.4.2, however, groundwater can either enter or exit the flow system through river boundaries. If the hydraulic head in the aquifer is greater than the river boundary elevation, groundwater discharges into the river. If the head in the aquifer is less than the river elevation, water from the river recharges the aquifer. This treatment of the effluent channel is based on the interpretation that the effluent channel is a losing stream in its upper reaches and a gaining stream in its lower reaches. The conductance of the effluent channel was varied during calibration as described below in Section F.4.5.3. The elevation of the effluent channel drain boundary was set based on both the topographic map and water elevations at effluent-channel stream gauges measured on May 5, 1999.

F.4.4.4 Specified-Head Boundary. Specified-head boundaries are used to describe the swampy area, the Northeast Cape Fear River, and Prince George Creek, which surround the model domain to the north, west, and south, as shown in Figure F-7. In all but the upper reaches of Prince George Creek, the elevation of this boundary was estimated to be 4 ft msl based on the topographic contour map. Along the upper reaches of Prince George Creek, the boundary is set to 7 ft msl, which also agrees with the topographic map.

F.4.4.5 No-Flow Boundary. The eastern lateral edge of the model is estimated to be perpendicular to the groundwater flow in this area. Groundwater does not flow perpendicular to flow paths, therefore this eastern edge of the model is established as a no-flow boundary for the flow system. Also, the bottom of the model was set as a no-flow boundary because there is no evidence of interaction between the modeled groundwater flow system and groundwater flow deeper than the lower model boundary.

F.4.4.6 Pumping Wells. The pumping wells were modeled as specified flux boundaries. The pumping rates were estimated from site-specific data as described in Section F.3.5.3. Although the screened interval for many of the site pumping wells is only adjacent to the lower model layer, the sand pack for these wells typically extends to the top of the principal aquifer. Therefore, most of the wells recover groundwater across the entire principal-aquifer thickness. In accordance with this behavior, these modeled pumping wells distribute the pumping rates across the upper and lower model layers.

F.4.5 Flow-Model Calibration

F.4.5.1 Calibration Data Set. The goal of model calibration is to minimize the differences between measured and simulated values (i.e., error). For the flow model, simulated groundwater elevations were compared with elevations measured on June 1-2, 1999 (Plate F-1). These data are a complete set of groundwater elevations from all of the active monitoring wells at the site. As described in Section F.3.3, groundwater flow patterns have been relatively consistent over time. Thus, the June 1999 water-level measurements are representative and complete and were thus selected for calibrating the flow model.

F.4.5.2 Calibration Error Criteria. Minimization of the error between the simulated and measured results was achieved through three methods: visual comparison of the head distributions, review of the calibration curves (x-y plots of the simulated versus the measured heads), and quantitative error criteria. Several quantitative error criteria are available, including: (1) mean error (ME), (2) mean absolute error (MAE), (3) root mean squared error (RMS), (4) RMS divided by the range of measured head values, (5) maximum residual, and (6) minimum residual.

The mean error is the arithmetic average of the residuals (a residual value is the measured head subtracted from the simulated head at a particular point):

$$ME = \frac{\sum_{i=1}^{n} (h_{meas} - h_{model})}{n}$$

where h_{meas} is a measured head value, h_{model} is the simulated head value, and n is the total number of measurements. The MAE is the mean of the absolute value of the residuals:

$$MAE = \frac{\sum_{i=1}^{n} |h_{meas} - h_{model}|}{n}$$

The RMS is calculated by squaring the residuals, taking an average of the squared residuals, and then taking the square root of the result:

$$RMS = \sqrt{\frac{\sum_{i=1}^{n} (h_{meas} - h_{model})^2}{n}}$$

The RMS divided by the range is calculated by dividing the RMS by the overall range of measured head values (the minimum measured head subtracted from the maximum measured head).

F.4.5.3 Calibration Procedures. Table F-2 documents the objectives, input parameters, and results of a series of flow calibration simulations, including a summary of the quantitative error criteria. Each row of this table presents the final result of a series of simulations. In each series, the parameter of interest was varied, and then the recharge was varied to minimize the calibration errors. Recharge was used as a default calibration parameter because of its uncertainty. The other parameter varied during the final steps of the flow model calibration was the hydraulic conductivity.

Results of simulation GE1 indicated that the initial estimates of recharge and conductivity give a reasonable regional groundwater flow pattern. However, the initial recharge estimates (see Section F.3.5.1) do not provide a satisfactory model calibration. This result is not surprising, considering the uncertainty of recharge estimates.

Based on the results of simulation GE1, recharge was varied manually during the development of simulation GE2. The final recharge distribution is shown in Figure F-12. The main difference between the manually calibrated recharge and the estimated recharge involves an increase in the recharge rate in areas where the hydraulic head difference between the surficial and principal aquifers was low. As discussed in Section F.3.5.1, a small head difference can indicate effective communication and greater flow between the aquifers.

Following simulation GE2, the flow patterns in the WT area continued to have a northeastern flow direction, although the measured flow direction and the plume orientation is to the northwest. This result led to a re-evaluation of the importance of the effluent channel on principal-aquifer groundwater flow. After interpreting that the effluent channel likely has an impact on the principal aquifer (see Section F.3.5.2), the effluent channel was added as a river boundary (simulation GE3). This modification reoriented the flow direction in the WT area to the northwest in agreement with the measured pattern. The flow patterns in the WT area were sensitive to the river boundary conductance values for the effluent channel. With a greater conductance, the flow had a greater northwestern trajectory, and with a lower conductance, the flow oriented more to the north and northeast. This result is expected, because the conductance controls the rate of flow between the river boundary (the effluent channel) and the aquifer. The final conductance values are given in Table F-1.

The final modifications to the model (simulation GE4) involved varying the hydraulic conductivity locally, particularly around selected pumping wells. These modifications allowed local control of simulated water elevations in order to better match the measured values. Because hydraulic conductivity is known to be heterogeneous at the site, all of the resulting conductivity values are reasonable. The final conductivity distribution in the upper model layer is shown in Figure F-13. The conductivity is 3.5 ft/day throughout the lower layer except in a small area around pumping wells WW-11 and WW-12; a greater conductivity of 30 ft/day was necessary in this local area to allow these wells to pump at the measured rates of 60 and 47 gpm, respectively. Simulation GE4 is the final, calibrated flow model subsequently used in transport modeling.

F.4.5.4 Calibration Results. Figure F-14 shows a plot of the simulated versus measured head values for the calibrated flow model. This figure includes the results of a linear regression of the calibration curve. The slope of the regression line (1.011) is very close to the ideal result of 1.0. Also, the coefficient of determination, or R^2 error (0.9644), is close to the ideal result of 1.0. The calibration statistics are provided in Table F-2 under simulation GE4. Plate F-1 compares the simulated and measured hydraulic head distribution. All of the calibration results indicate very good agreement between measured and simulated groundwater elevations.

F.4.6 Flow-Model Results

Figure F-7 shows the regional simulated heads over the entire model domain. Groundwater across most of the northeastern GE property is captured by this system of pumping wells. *Area Investigation Report* Figure 3-9 presents flow paths and travel times in the WT area resulting from the flow model. This figure shows principal-aquifer groundwater flowing from the WT Facility to the north-northwest toward the effluent channel. The travel time is approximately 4 to 5 years for groundwater to flow from the north edge of the WT Facility to the leading edge of the nitrate plume. Once crossing the effluent channel, the groundwater is influenced by the capture zone of site pumping wells and flows to the northeast toward these wells.

It is important to note that, within the WT investigation area, there are relatively few groundwater-elevation measurement points north of the effluent channel. Considering that groundwater flow patterns in this area are relatively sensitive to influences from the pumping wells, the effluent channel, and surrounding groundwater flow, there is some uncertainty associated with the model predictions in that portion of the WT investigation area. Follow-up investigation work in the WT area described in *Area Investigation Report* Section 7 includes the installation of 3 monitoring wells in this area, which should help resolve some of the uncertainty.

F.5 Transport Model Development

A numerical transport model was developed to enhance the understanding of the nitrate plume and to allow predictions of plume behavior into the future. This section describes the development of the transport model, including the code, the finite-difference grid, input parameters, and boundary conditions.

F.5.1 Code Description

The transport model, MT3D^{96}, is a three-dimensional, block-centered, finite-difference numerical model developed by S.S. Papadopulos & Associates, Inc. The model is widely tested and used. MT3D^{96} can simulate the advection, dispersion, sorption, and first-order degradation of dissolved constituents in groundwater. MT3D^{96} directly uses results from MODFLOW for the flow field. The MT3D^{96} pre- and post-processor Visual MODFLOW was used to prepare input files and to analyze the results.

F.5.2 Finite-Difference Grid

The finite difference grid was identical to the grid used in the calibrated flow model shown in Figure F-8.

F.5.3 Input Parameters

Table F-3 summarizes the transport model input parameters for nitrate. Sorption is not included, because nitrate is a non-sorbing anion. The dispersivity values were established based on the scale of the plume (see Section F.3.4.3) and model sensitivity analysis. A relatively low value was chosen to be conservative, thereby minimizing the potential for mixing. The model results were relatively insensitive to the dispersivity in this low range. The degradation rate was the primary parameter varied during transport model calibration as described in Section F.5.5. The final half life in the degradation model scenario was 1.12 years, which is well within the range of denitrification rates reported in the literature (as described in *Area Investigation Report* Section 5.1.1).

Table F-3 also presents the transport modeling input parameters for ammonium. *Area Investigation Report* Sections 1.1 and 5.1.2 provide discussions of ammonia/ammonium equilibrium and the rationale for the interchangeability of these terms. The input parameters for ammonium are the same as for nitrate, except ammonium undergoes sorption and does not degrade. The effectiveness of ammonium sorption is conservatively set below the effectiveness reported in the literature for sandstone aquifers as described in Section F.3.4.2.

F.5.4 Boundary Conditions

The transport model directly uses the flow-model velocity field. Therefore, the transport model is subject to all of the flow-model boundary conditions, including the swampy area, the effluent channel, and recharge. In addition, the calibration simulations discussed below in Section F.5.5 include specified concentration boundaries to represent the former contaminant source areas. These simulations represent conditions during which leakage is believed to have occurred (prior to the relining of the WT basins). Because the basins have been relined, none of the predictive simulations described in Section F.6 include source boundary conditions.

F.5.5 Transport Model Calibration

Calibration of the transport model was achieved by comparing simulated concentrations with current concentrations measured at the site.

Transport within groundwater systems is highly complex. Not only are constituents typically subject to multiple potential reactions (e.g., sorption, biodegradation, oxidation, precipitation), but the subsurface is also usually highly heterogeneous, with different flow and transport conditions present over small spatial scales. In addition, the timing and mass of the original contaminant sources are typically impossible to accurately reconstruct. Given the complexity of transport processes and site operational histories, transport modeling is uncertain. Therefore, transport model calibration often relies more on qualitative rather than quantitative comparisons between measured and simulated results. The emphasis of transport model calibration during this study was thus on visual comparison between the measured and the simulated concentration distributions rather than on quantitative error criteria.

F.5.5.1 Nitrate Transport Model Calibration. A series of calibration and sensitivity-analysis simulations was performed to estimate reasonable ranges for the input parameters and to ensure model reliability. The calibration of the nitrate transport model involved varying the degradation rate and the source concentration until a simulated, stable plume provided a good match to the measured plume. Table F-4 documents the series of transport-model calibration simulations.

Results of this calibration effort are shown in *Area Investigation Report* Figure 5-5. As this figure indicates, the simulated plume matches the measured values quite well. The only measurements falling outside the simulated concentration ranges indicated in the figure are from borings WTB-33, WTB-29, and WTB-30. In each case, the concentration in an adjacent monitoring well (WT-7B, WT-13B, and WT-14B, respectively) does accurately match the simulated results. Therefore, there is some discrepancy between laboratory analytical results for in-situ groundwater samples taken from certain borings at specific aquifer horizons and for nearby monitoring-well samples taken from a larger screened interval within the aquifer. Nevertheless, the model closely matches the maximum concentrations measured at the monitoring wells.

As mentioned above, it was assumed during the transport model calibration that the currently measured plume is stable. A stable plume remains unchanged over time because the contaminant mass entering the aquifer is balanced by the mass being attenuated. However, due to the absence of nitrate monitoring data prior to 1998, it is impossible to determine whether the existing plume is indeed in a stable configuration. Nevertheless, the assumption of a stable plume allows the model to subsequently predict the minimum possible future migration of the plume after the nitrate basin liners were replaced (the degradation model scenario described below in Section F.6). The maximum potential future migration of the plume was then estimated by eliminating the degradation attenuation mechanism (the no-degradation model scenario described below in Section F.6). Thus, these simulations together bracket the potential future behavior of the nitrate plume, even given the uncertainties about nitrate degradation mechanisms and the contaminant-release history. It is important to note that even though the calibration model setup minimizes potential future migration by assuming a stable plume, the resulting degradation rate (a half life of 1.12 years) is well within reported field rates for denitrification. Further, considering the accurate match between the simulation and the measured results (*Area Investigation Report* Figure 5-5), the estimated degradation rate is a reasonable possibility for the current plume and so was used in the degradation modeling scenario.

F.5.5.2 Ammonium Transport Model Calibration. Ammonium is of less concern than nitrate, because there is no groundwater standard for ammonium and the potential health effects are less significant. However, ammonium transport simulations provide an additional model calibration and demonstrate the ability of the model to reproduce a reasonable ammonium distribution. Figure F-15 shows the resulting simulated distribution of ammonium along with measured concentrations in the WT area. As this figure indicates, the model reproduces the measured distribution reasonably well. Most of the measured concentrations are within the simulated ranges shown in Figure F-15. However, boring WTB-32 and well WT-16B do show low measured ammonium concentrations, and the simulated plume does not reach these locations. This evidence suggests that there may be some inconsistency between the simulated and actual flow patterns to the north of the effluent channel or that flow patterns in this area may have varied over time. Nevertheless, the concentrations at these locations are low (8.56 and 3.20 mg/L for WTB-32 and WT-16B, respectively), which could represent background conditions. Further monitoring in this area to the north of the effluent channel will help resolve some of the uncertainty in the flow patterns in this area. Because ammonium is of less concern than nitrate, no predictive simulations were performed for ammonium transport.

F.6 Predictive Transport Simulations

The uncertainty about the timing and the characteristics of the release of contamination from the source area makes predictive modeling of contaminant transport in the principal aquifer uncertain. It is unknown when and how much nitrate liquid reached the principal aquifer, nor the contaminant concentrations that resulted after the released material passed through the surficial aquifer and the semiconfining layer. In addition, it is unknown how much nitrate is being transformed into other compounds by processes described in *Area Investigation Report* Section 5.1. Given these uncertainties, the predictive transport simulations were designed to bracket the potential future behavior of the plume with two modeling scenarios -- a degradation scenario minimizing the potential future migration, and a highly conservative no-degradation scenario maximizing the potential future migration. The degradation scenario includes a reasonable rate of nitrate degradation. The no-degradation scenario does not include any nitrate degradation.

Because the release from the nitrate basins has been eliminated, there is no continuing source of contamination in either model scenario. The initial concentrations for both scenarios correspond to the calibrated nitrate plume that matches currently measured conditions (the plume shown in *Area Investigation Report* Figure 5-5). The migration of the plume from these initial concentrations is then predicted into the future using the transport scenarios described in Table F-3.

Area Investigation Report Figures 5-6 and 5-7 show results of the degradation scenario. With these transport assumptions, the nitrate concentration falls below the North Carolina groundwater standard of 10 mg/L (as N) within 5 years. Also, the plume remains within approximately 900 ft of the north edge of the WT Facility throughout this period. The initial plume is assumed to be stable and fed by a continuous source of nitrate entering the principal aquifer. Therefore, in the degradation scenario, once the nitrate source is removed the plume does not migrate farther downgradient. Rather, the plume maintains a position similar to the initial condition, and experiences decreasing concentrations over time due to natural-attenuation processes.

Area Investigation Report Figures 5-8 and 5-9 show results of the conservative no-degradation scenario. With these transport assumptions, the nitrate concentration falls below 10 mg/L (as N) within 14 years. The plume does migrate downgradient, however it is fully captured by pumping wells WW-13 and WW-14 (the scenario assumes current pumping conditions are maintained). As described above, the no-degradation scenario assumes no attenuation processes are occurring other than mixing (dispersion) with groundwater that contains no nitrate or low concentrations of nitrate. In areas of converging groundwater flow (e.g., the area of depressed groundwater levels surrounding the GE pumping-well network), mixing can be a particularly effective mechanism for lowering concentrations. This effectiveness results from increased groundwater velocities in these areas and from the fact that groundwater is converging from a broad area with little contamination into a smaller area. Therefore, even in the absence of degradation (the conservative no-attenuation scenario), decreasing concentrations, due to mixing, limit the predicted time that the nitrate plume will be above 10 mg/L (as N) to less than 14 years.

F.7 Summary and Conclusions

The following statements summarize the modeling efforts and the implications for the principal-aquifer contamination in the WT area:

- A numerical model of groundwater flow area was developed and quantitatively calibrated to groundwater levels measured at the site in June 1999.
- Simulated groundwater flow travel times from the nitrate basins to the leading edge of the plume are between 4 and 5 years, in agreement with manual calculations.
- Numerical models were developed that describe the fate and transport of the nitrate and ammonium in groundwater. These models were qualitatively calibrated to measured site conditions.
- Nitrate transport modeling predicts that, if no natural-attenuation processes are occurring, the ammonia and nitrate plumes would be recovered by wells WW-13 and WW-14 in GE's active pumping-well network north of the effluent channel. In this highly conservative scenario, concentrations of nitrate exceeding the North Carolina groundwater standard of 10 mg/L (as N) are predicted to reach well WW-14 within 5 years from present, and the maximum nitrate concentration in groundwater is predicted to fall below the 10 mg/L regulatory level within approximately 14 years.
- Given a degree of natural attenuation that is reasonable for this geochemical system, nitrate transport modeling predicts that the nitrate plume would be stable and would degrade in place over time. In this scenario, groundwater nitrate concentrations exceeding the North Carolina groundwater standard of 10 mg/L (as N) are not predicted to reach well WW-14, and the maximum nitrate concentration in groundwater would degrade to below the 10 mg/L regulatory level within approximately 5 years.

F.8 References

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FIGURES

Figure F-1 Historical Principal-Aquifer Water Levels in the WT Area

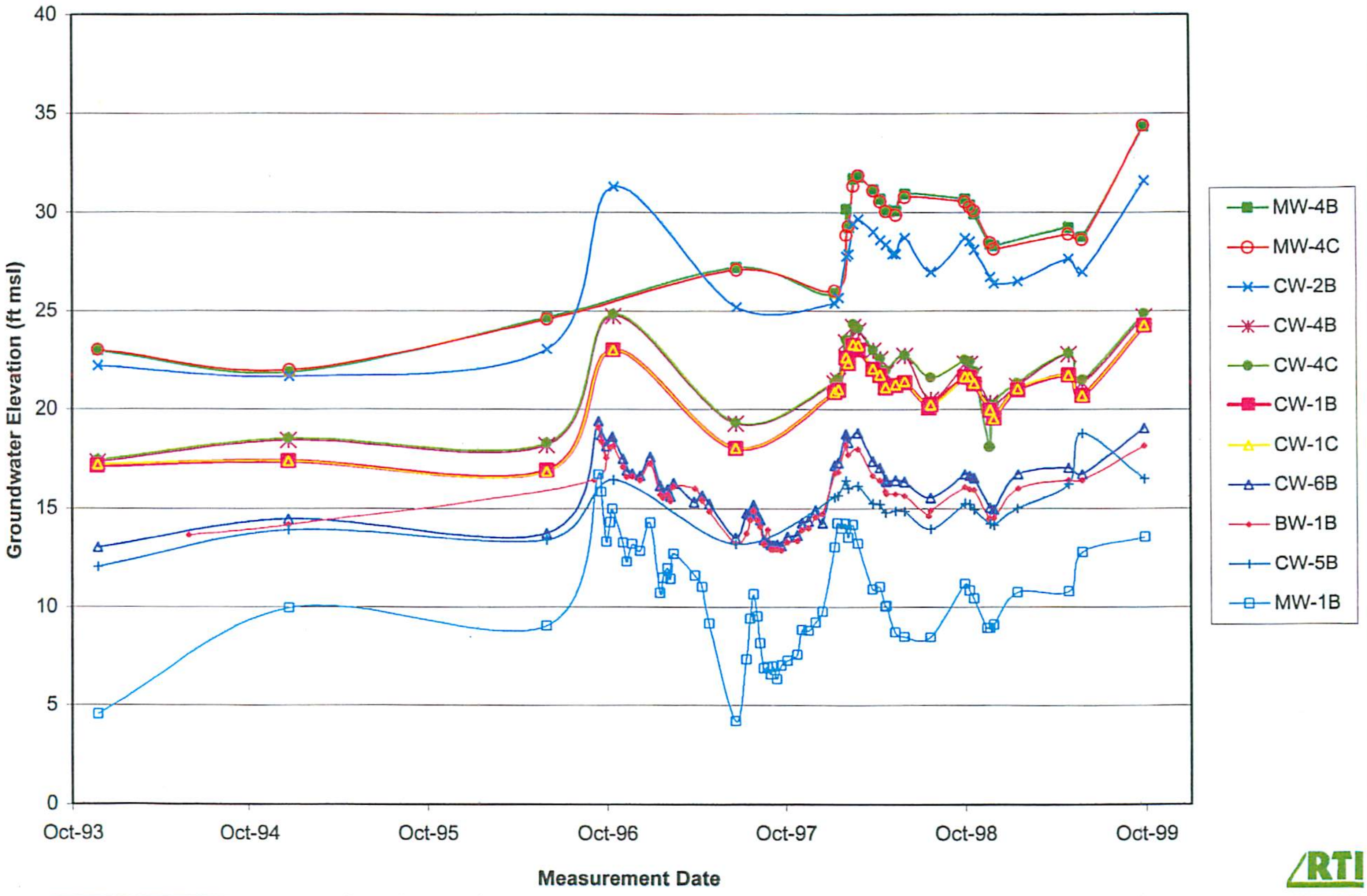
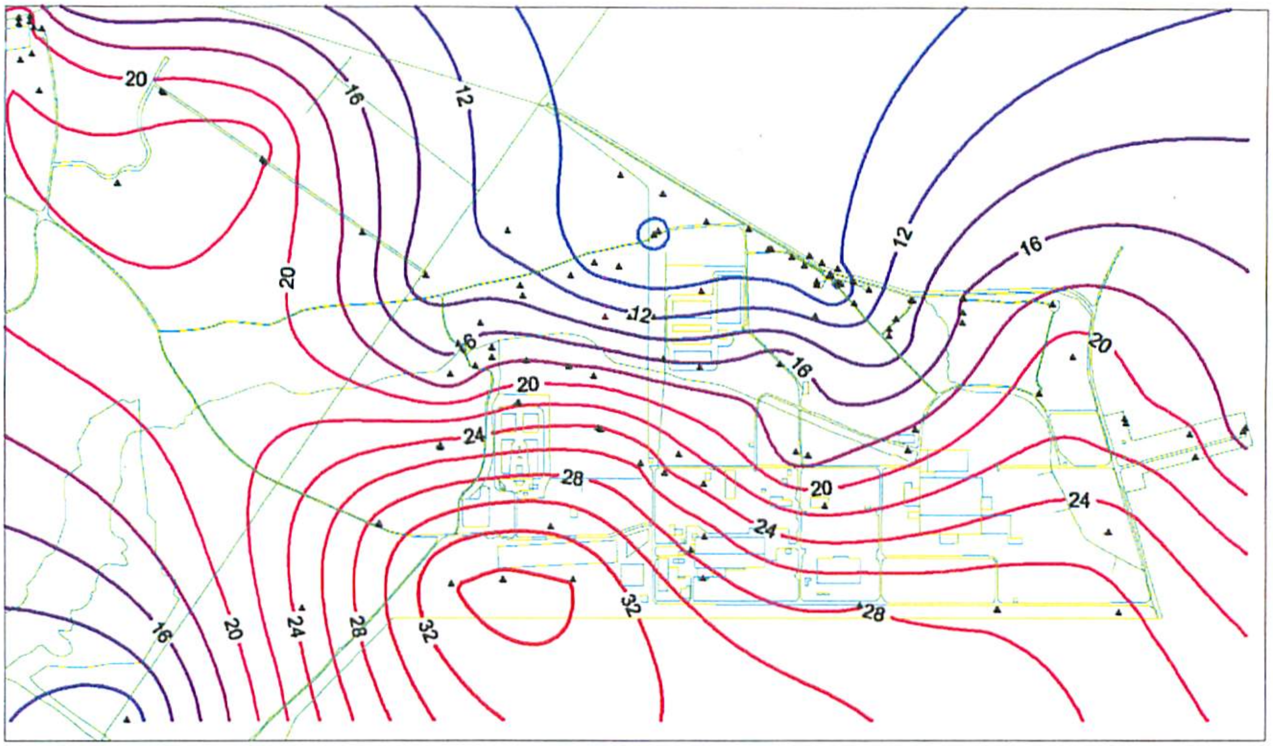
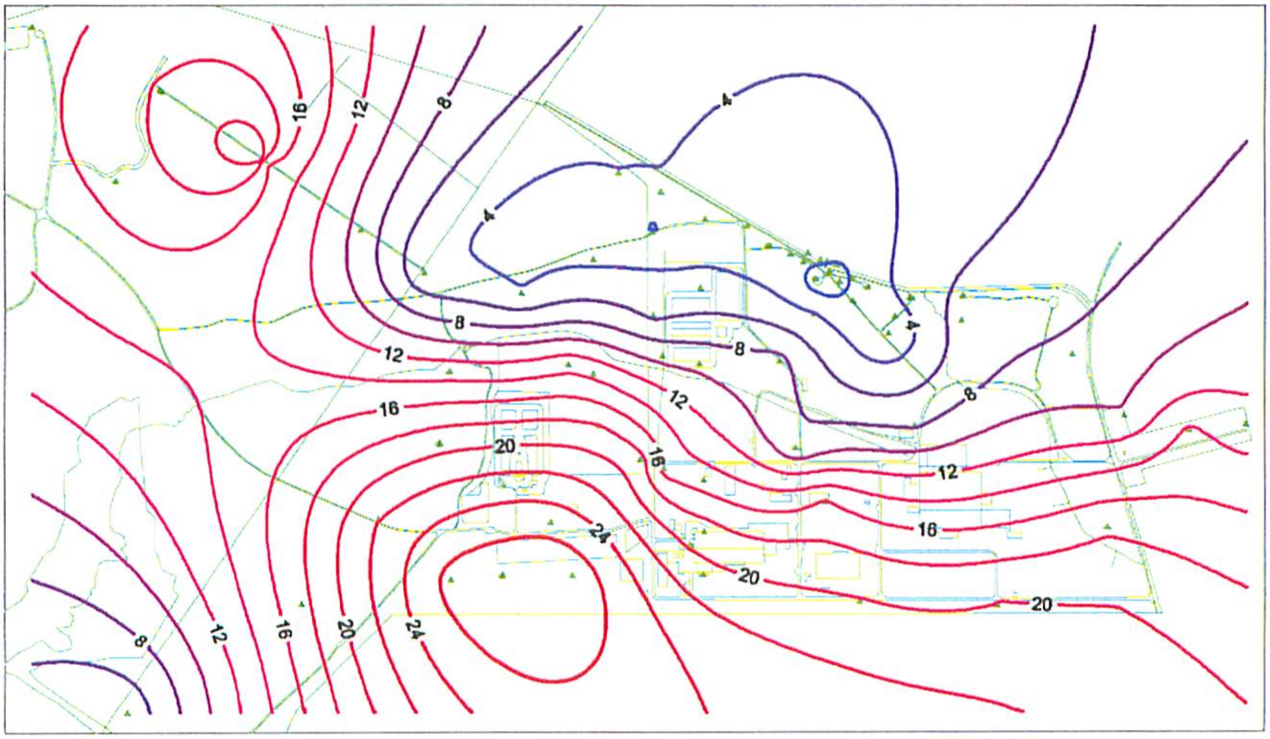


Figure F-2 Comparison of Principal-Aquifer Flow Patterns at High and Low Water Levels



Relatively high water-level conditions measured October 1999



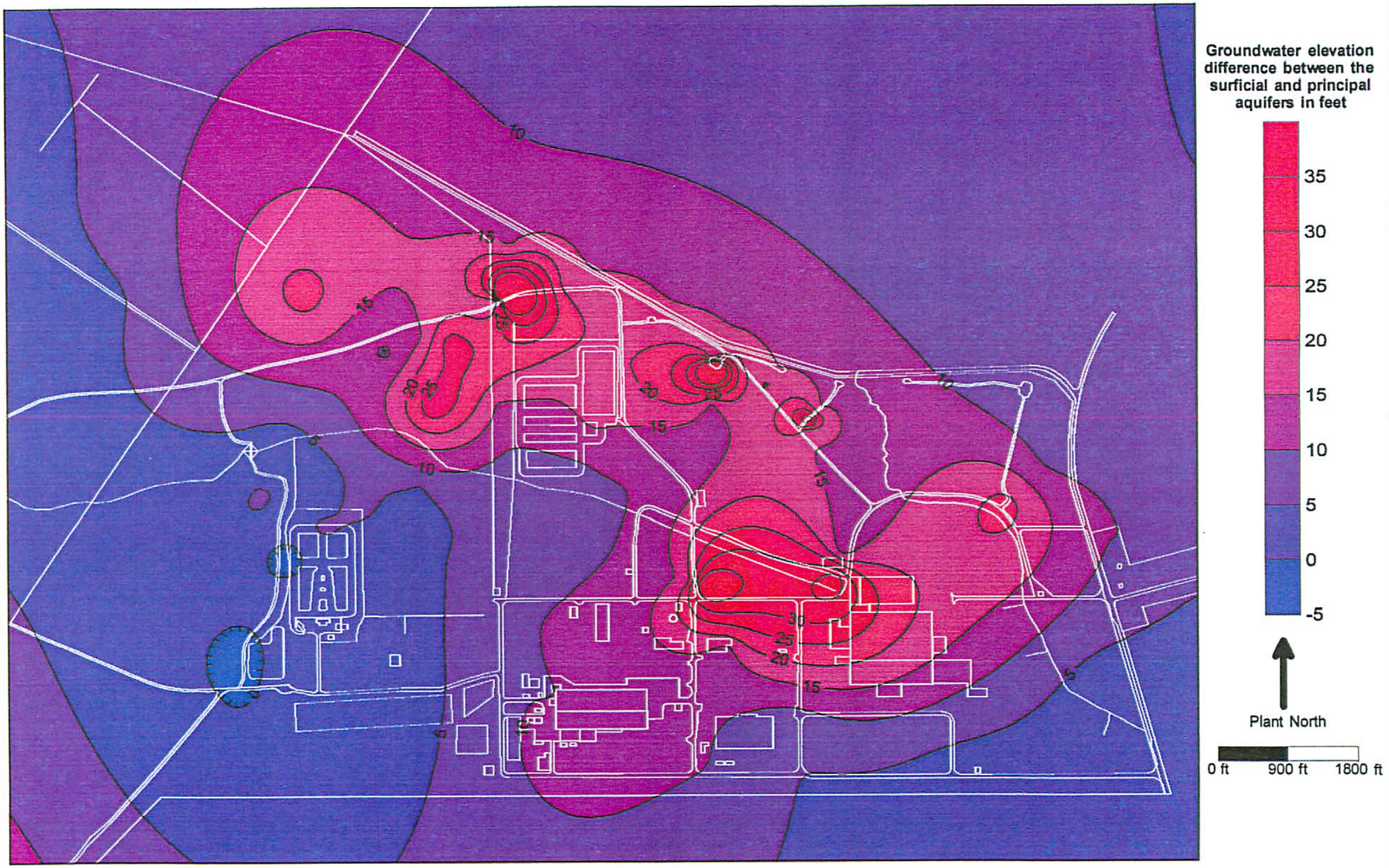
Relatively low water-level conditions measured June 1997

Legend

—24— Principal-aquifer ground-water elevation in feet msl

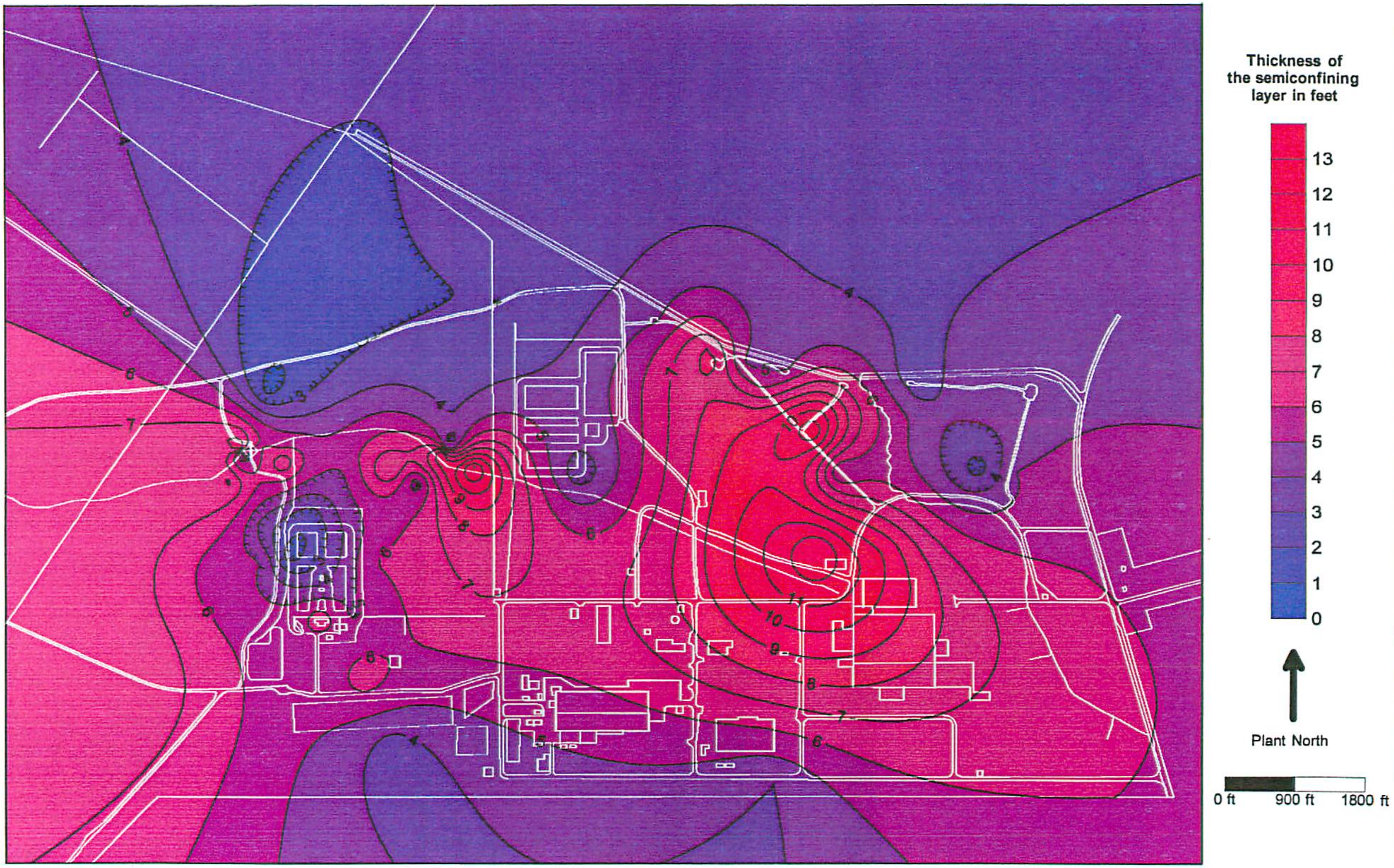
Notes: Water-level contours were interpolated from measured groundwater elevations using a linear kriging procedure. Water levels in recovery wells were not included in the interpolation due to pumping well head loss.

Figure F-3 Groundwater Elevation Difference Between the Surficial and Principal Aquifers



Note: This estimate was developed by kriging the groundwater elevations measured in the aquifers in June 1999.
The principal-aquifer elevations were then subtracted from the surficial-aquifer elevations.

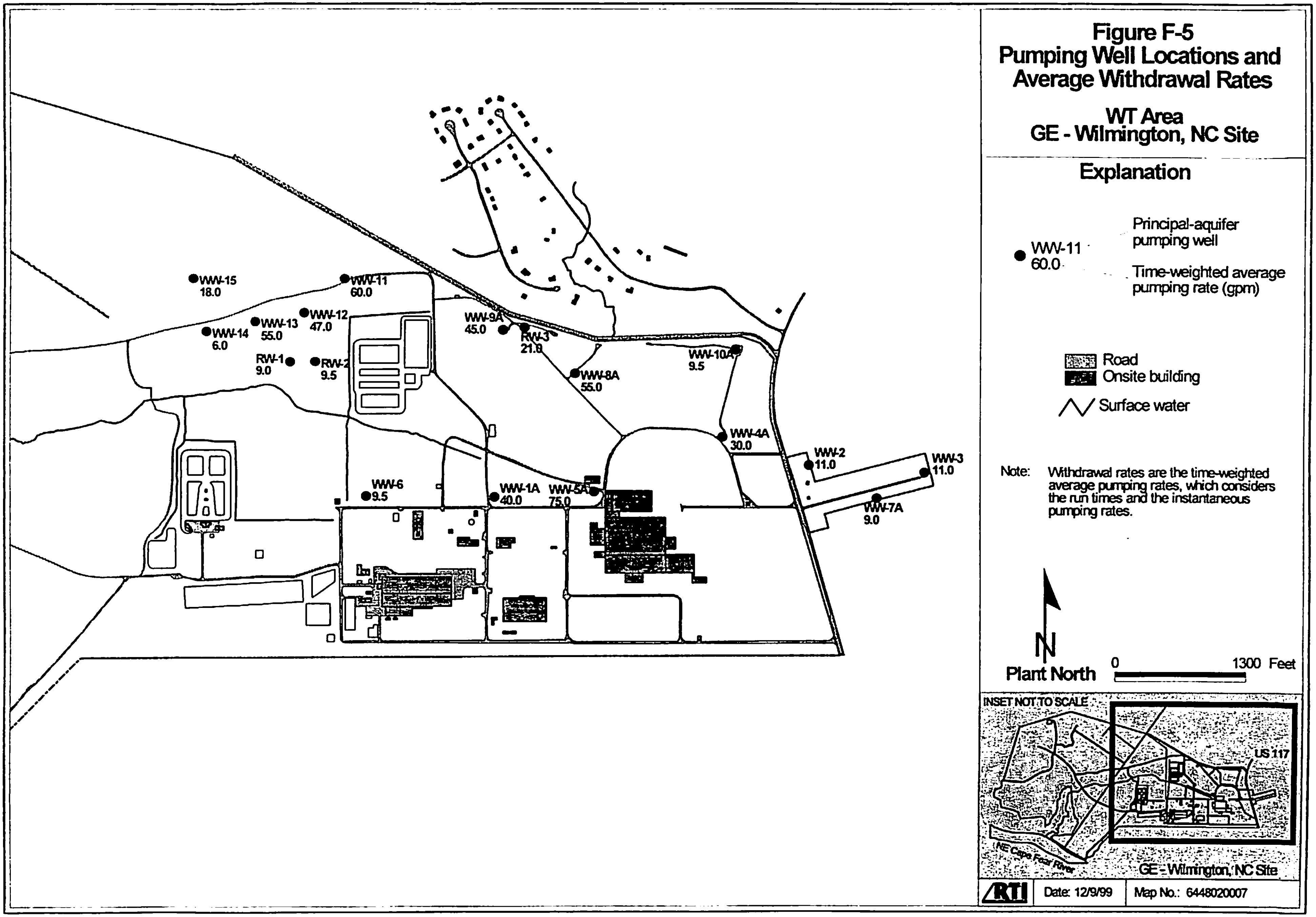
Figure F-4 Thickness of the Semiconfining Layer



Note: This estimate was developed by kriging the top and bottom surfaces of the semiconfining layer based on well and boring logs across the site. Then the bottom surface was subtracted from the top surface.

Figure F-5
Pumping Well Locations and Average Withdrawal Rates

WT Area
GE - Wilmington, NC Site



Explanation

● WW-11 — Principal-aquifer pumping well
60.0 — Time-weighted average pumping rate (gpm)

▨ Road
■ Onsite building
/\/ Surface water

Note: Withdrawal rates are the time-weighted average pumping rates, which considers the run times and the instantaneous pumping rates.

RTI | Date: 12/9/99 | Map No.: 6448020007

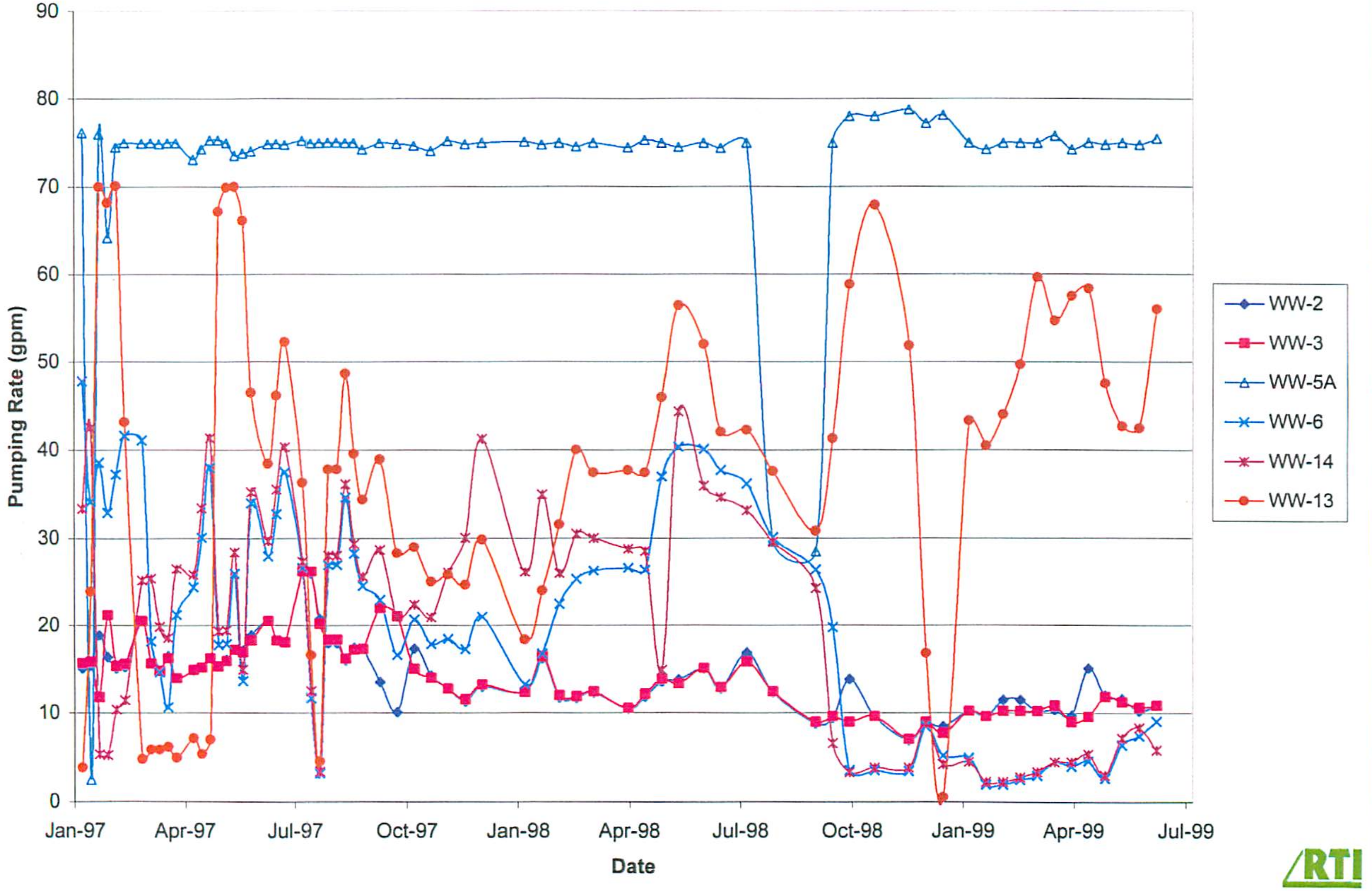
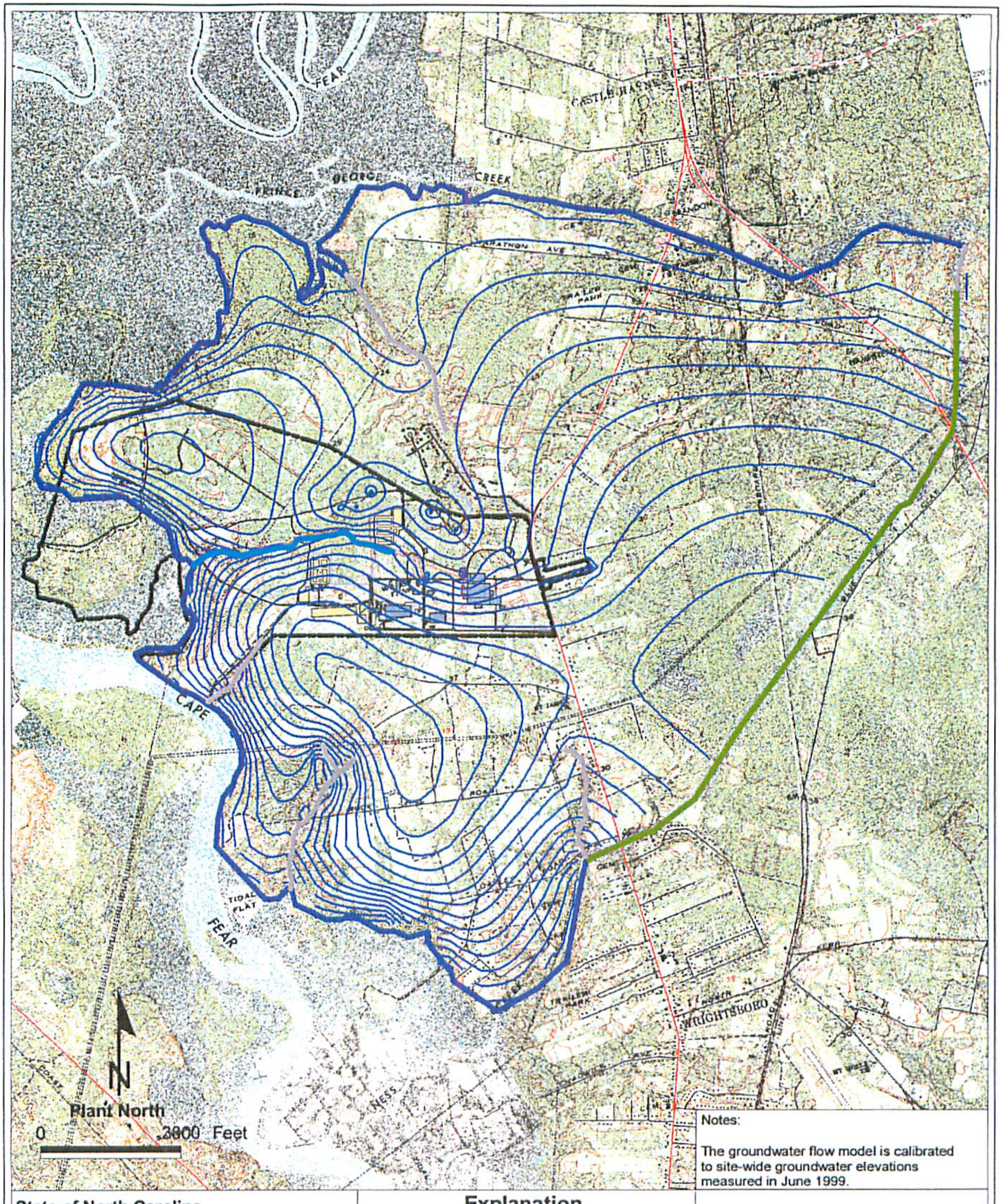


Figure F-6 Time-Weighted Average Pumping-Well Withdrawal Rates
(January 1997 through July 1999)



Notes:

The groundwater flow model is calibrated to site-wide groundwater elevations measured in June 1999.

State of North Carolina

Inset not to scale

RTI | Date: 11/17/99 | Map No.: 6448020001

Explanation

Simulated groundwater elevations (ft MSL)

Drain boundary

No flow boundary

River boundary

Constant head boundary

Low-lying swampy area

GE Property Boundary

Figure F-7

Model Domain and Simulated Regional Principal-Aquifer Groundwater Elevations

GE - Wilmington, NC Site

Figure F-8
Finite-Difference Grid

WT Area
GE - Wilmington, NC Site

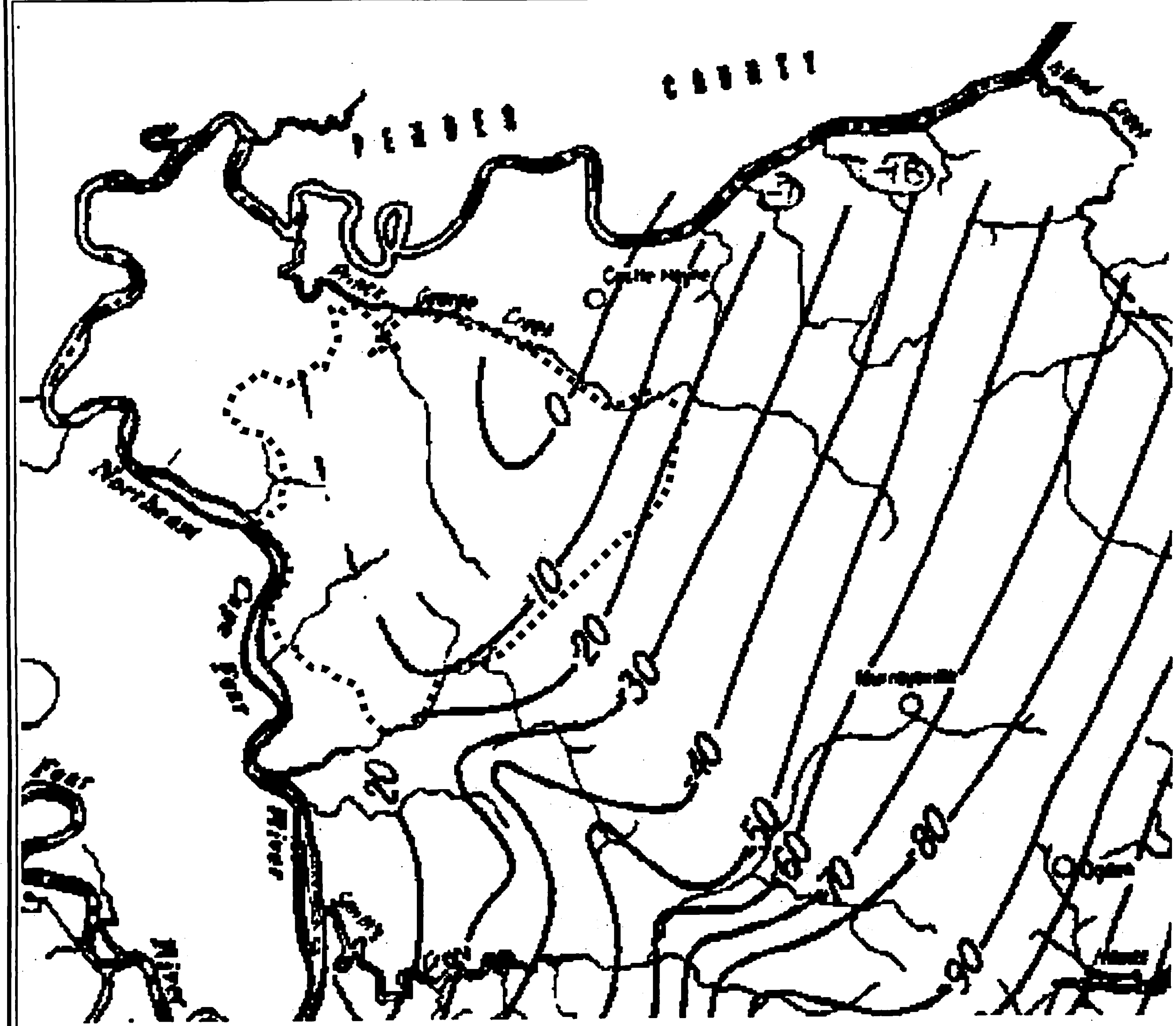
Date: 12/9/99

Map No.: 6448020007

Figure F-9

Top Elevation of the Principal Aquifer

WT Area
GE - Wilmington, NC Site



Explanation

—120— — —

STRUCTURE CONTOUR
Shows altitude of top of sandstone aquifer. Contour interval 10 feet. Datum is mean sea level.

• • • • • Approximate model domain boundary

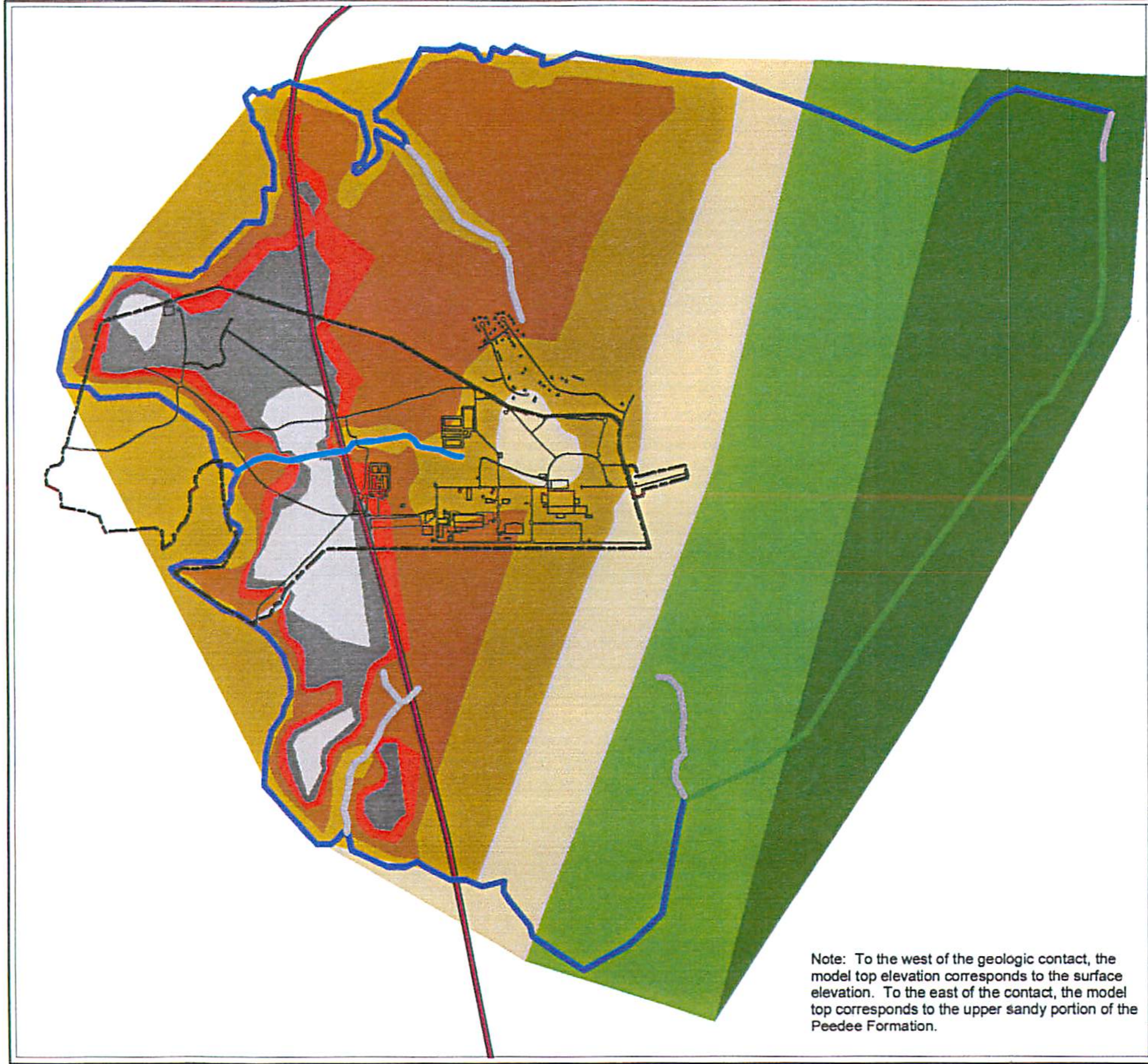
Note: The principal aquifer is the "sandstone aquifer" identified in this figure, after Bain (1970).

RTI

Project: 6448-020
Date: 12/9/99
File: Fig F-9.ppt

Figure F-10
Model Top Elevation

WT Area
GE - Wilmington, NC Site



Note: To the west of the geologic contact, the model top elevation corresponds to the surface elevation. To the east of the contact, the model top corresponds to the upper sandy portion of the Peedee Formation.

Explanation

Model Top Elevation Range (ft msl)

- ☐ 25 - 30
- ▨ 20 - 25
- 🟥 15 - 20
- 🟧 10 - 15
- 🟨 5 - 10
- 🟨 0 - 5
- 🟩 -10 - 0
- 🟩 -20 - -10

Geologic contact -- western extent of the upper sandy portionof the Peedee Formation, after Bain (1970).

Drain boundary

No flow boundary

River boundary

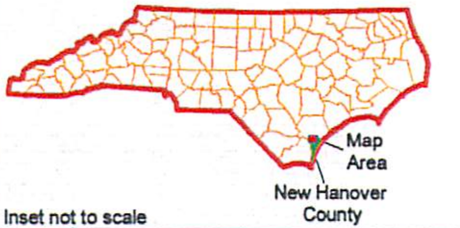
Constant head boundary

GE Property Boundary

Plant North

0 3600 Feet

State of North Carolina



Inset not to scale

RTI Date: 12/9/99 Map No.: 6448020007

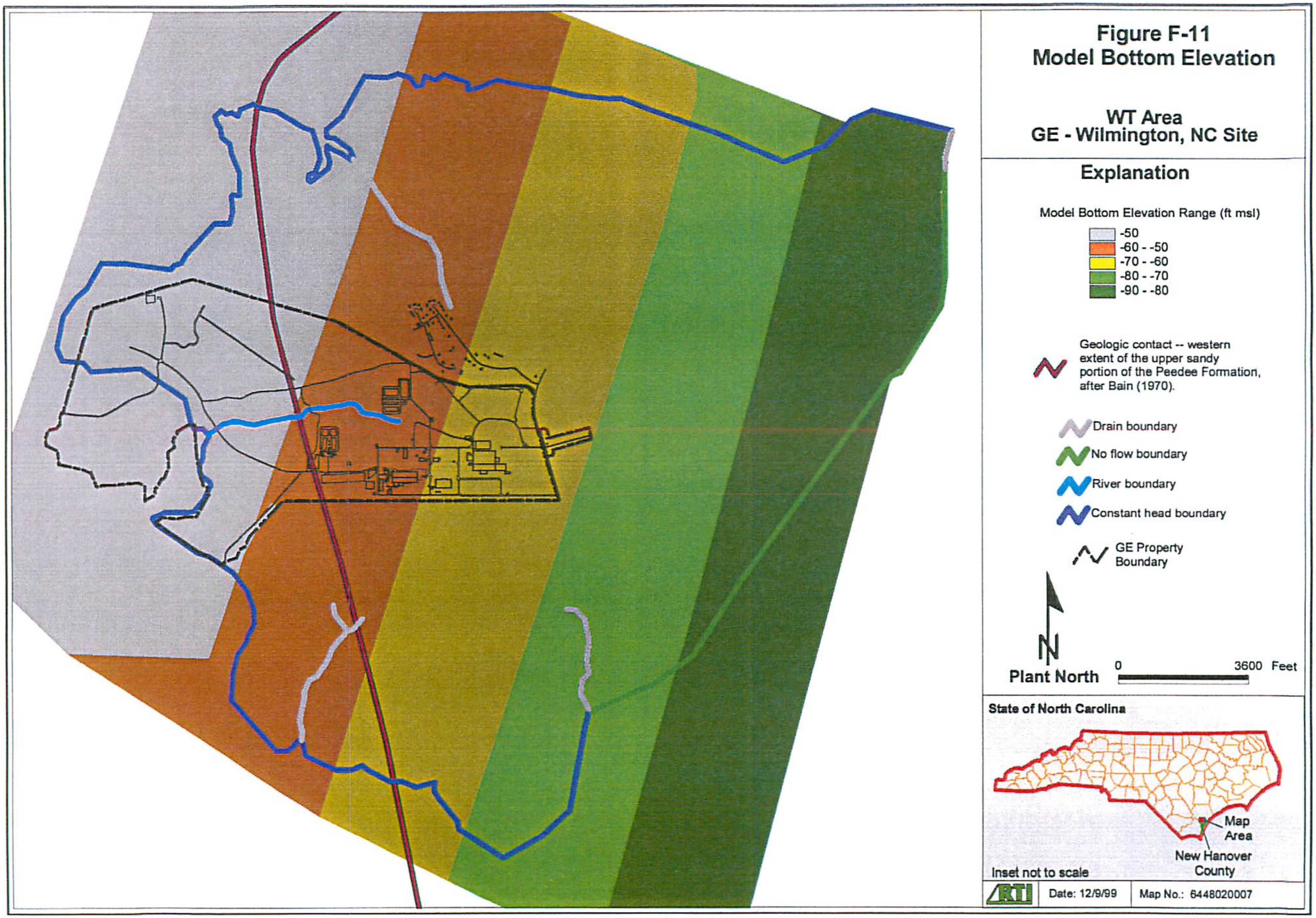
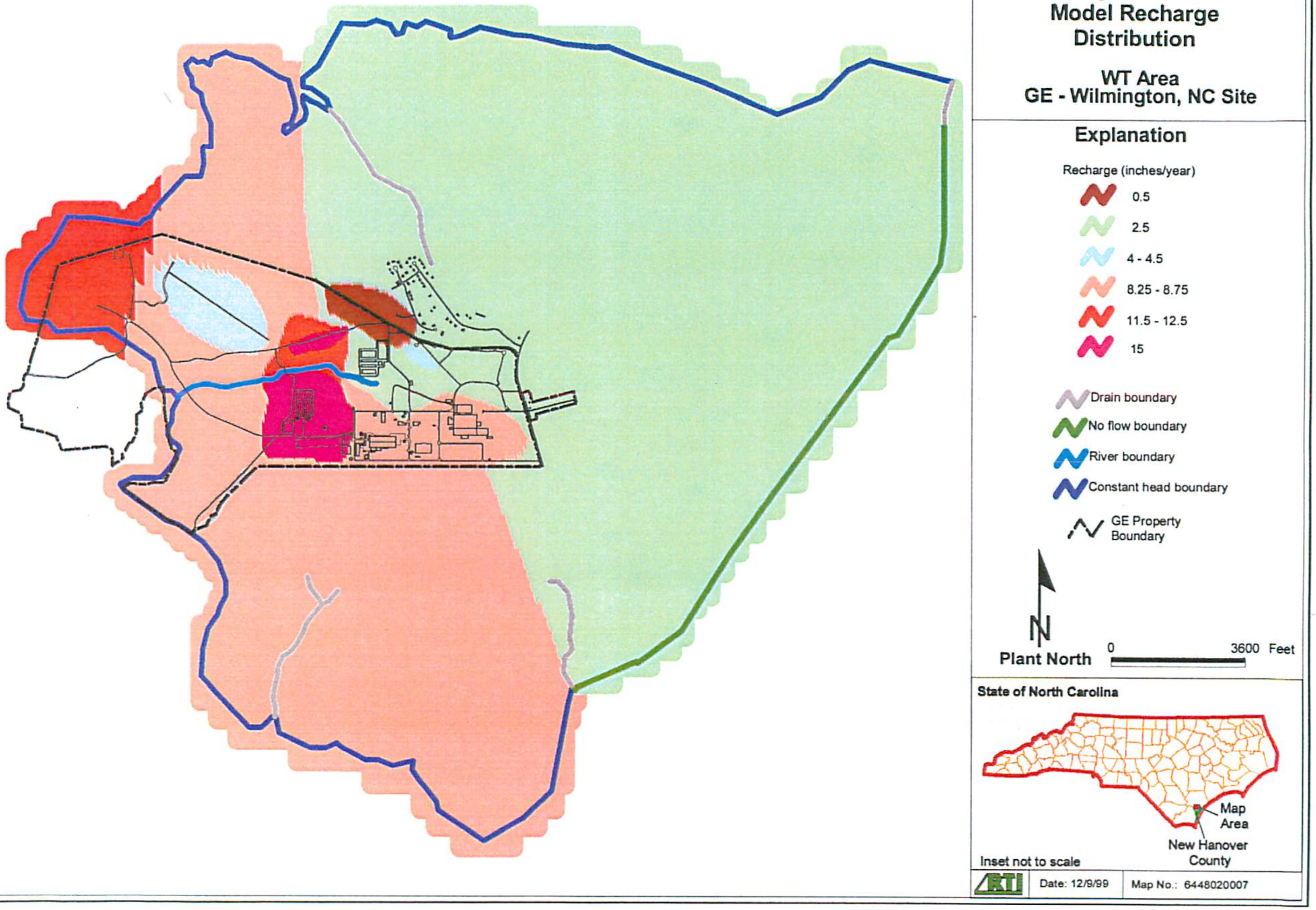


Figure F-11
Model Bottom Elevation

WT Area
GE - Wilmington, NC Site

Figure F-12
Model Recharge Distribution

WT Area
GE - Wilmington, NC Site



Date: 12/9/99

Map No.: 6448020007

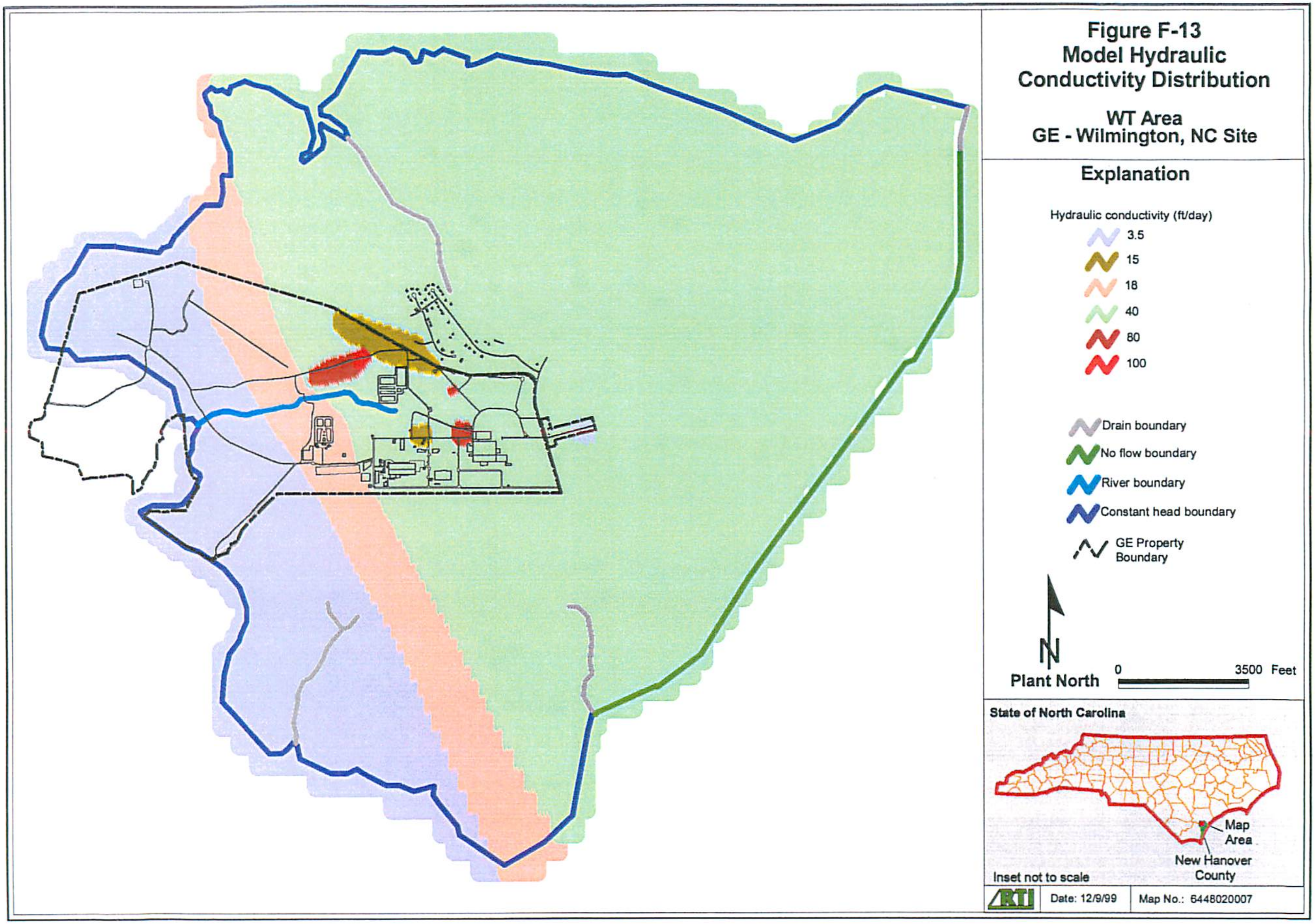
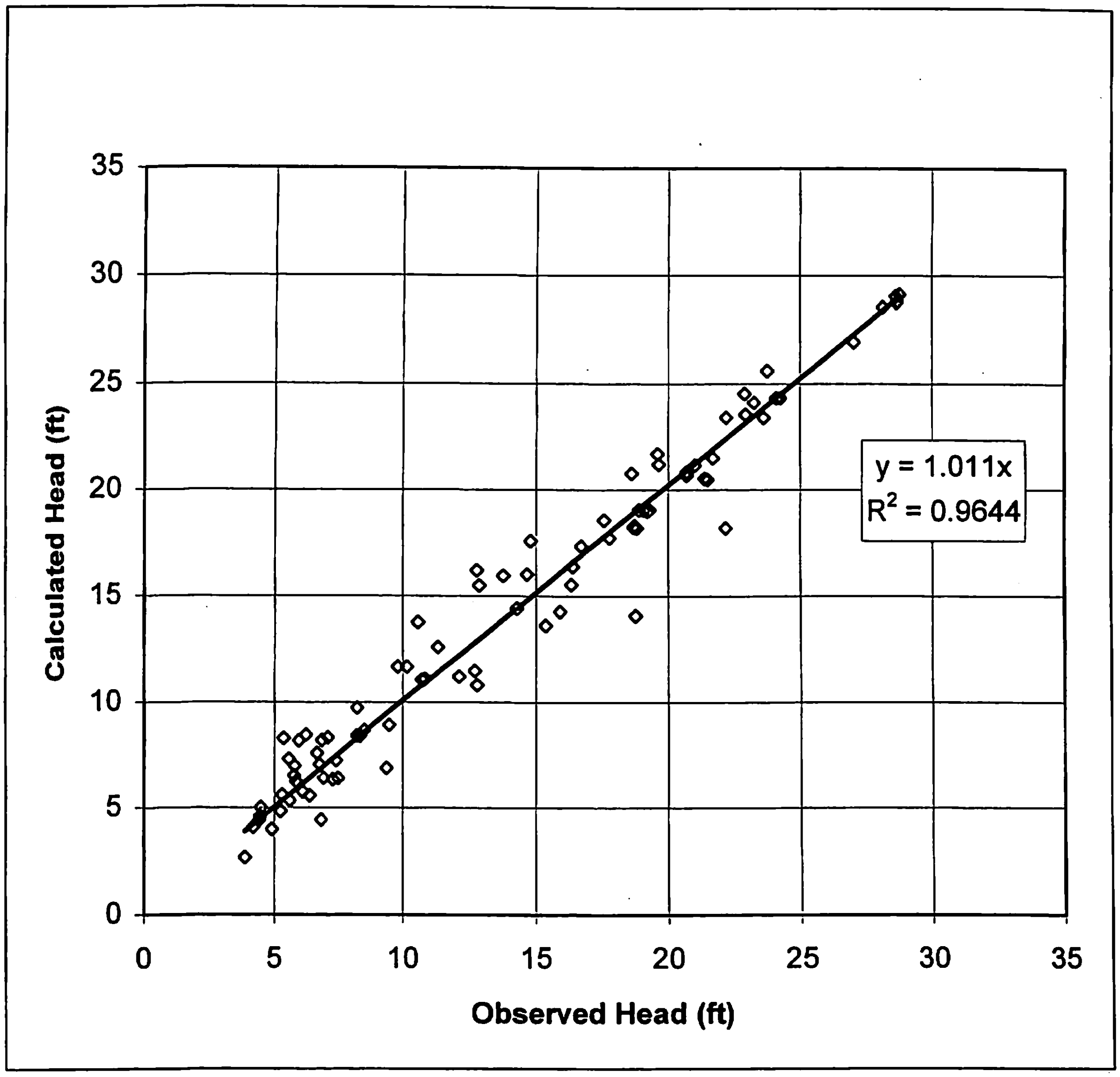


Figure F-13
Model Hydraulic Conductivity Distribution

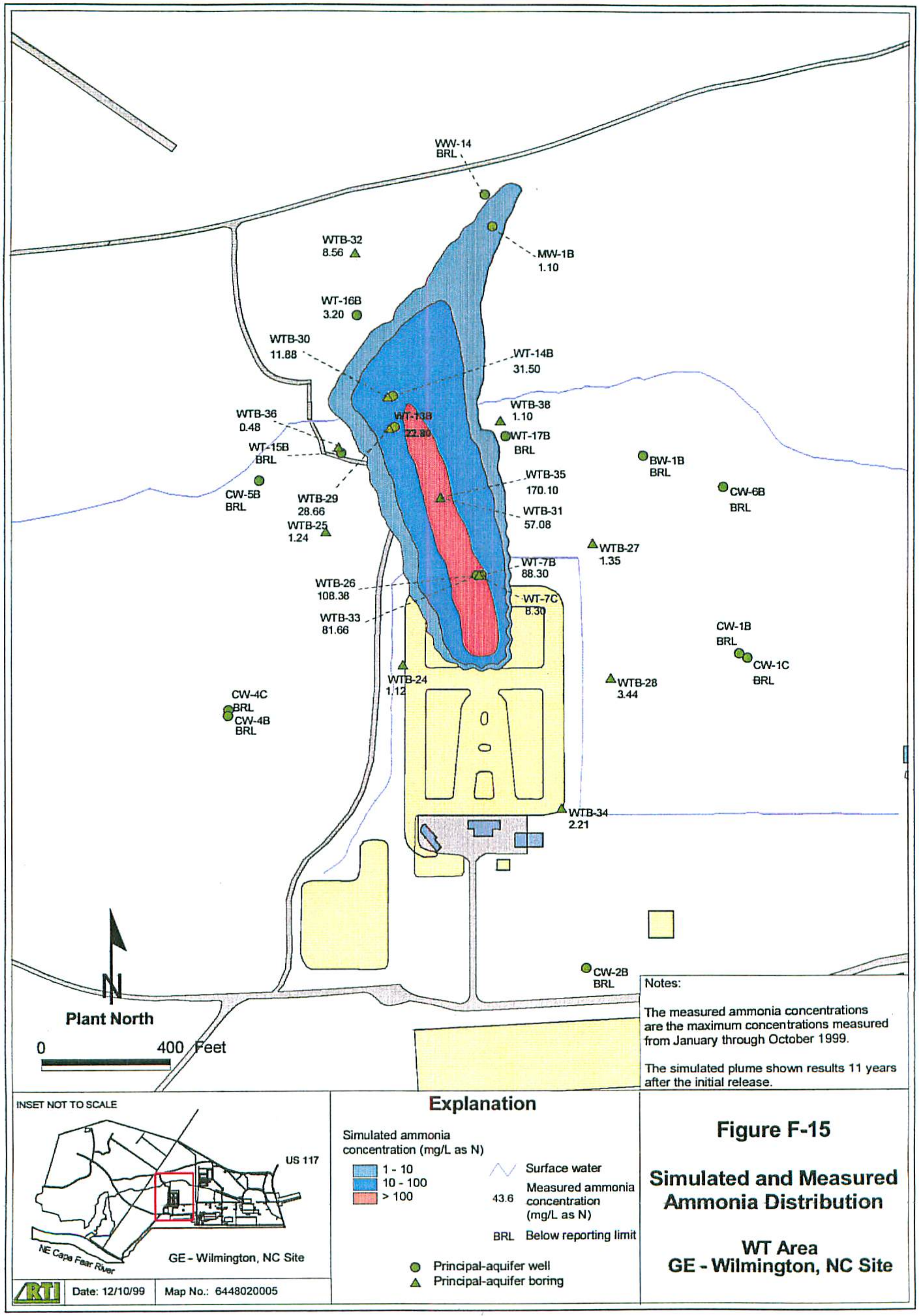
WT Area
GE - Wilmington, NC Site

Figure F-14 Flow-Model Calibration Curve



Calibration Statistics

Max Residual	4.71
Min Residual	-3.44
Mean	-0.25
Absolute Mean	1.01
Max Observed	28.75
Min Observed	3.86
Range	24.89
Number of Observations	89
Sum of Squares	175.64
Root Mean Squared	1.40
RMS/Range (%)	5.64



Notes:

The measured ammonia concentrations are the maximum concentrations measured from January through October 1999.

The simulated plume shown results 11 years after the initial release.

Figure F-15

Simulated and Measured Ammonia Distribution

WT Area
GE - Wilmington, NC Site

TABLES

Table F-1
Summary of Flow Model Parameters

Parameter	Value	Basis
Porosity	0.3	Typical value for fine to medium sands.
Recharge	see Figure F-12	see Sections F.3.5.1 and F.4.5.3
Horizontal Hydraulic Conductivity	see Figure F-13	see Sections F.3.4.1 and F.4.5.3
Stream Drain Boundary Elevations	variable	Topographic Map
Stream Drain Boundary Conductance	2000 ft^2/day	Estimated during calibration. (High enough for the drains to act as specified head boundaries.)
Effluent Channel River Boundary Elevation	variable	Measured stream gauge elevations; Topographic map
Effluent Channel River Boundary Conductance	Between 574 and 957 ft^2/day	Calibration to control the influence of the effluent channel on flow patterns (see Section F.4.5.3)
Elevations of Hydrogeologic Units	variable	Site boring and well logs; Bain (1970); Topographic map; Geologic interpretation
Swampy-Area Constant Head Elevation	4 feet	Topographic map

Table F-2
Flow-Model Calibration Simulations

Simulation	Objective	Input Parameters	Results
GE1	Initial conductivity estimates. Recharge determined from independent estimates.	$K_{l1,east}$: 40 ft/day; $K_{l1,central}$=20 ft/day; $K_{l1,west}$: 3.5 ft/day; K_{l2}: 3.5 ft/day; Recharge: between 3 and 26 in/yr	Mean error: -4.04 Mean absolute error: 6.54 RMS error: 7.94 Scaled RMS error: 31.93 % Regional flow patterns are reasonable, however the water levels are too low, and the flow direction in the WT area is to the northeast rather than the northwest, as measured. There is a systematic error evident in the calibration curve, whereby the modeled heads around many of the pumping wells are too high.
GE2	Vary recharge estimate from the independent estimate.	$K_{l1,east}$: 40 ft/day; $K_{l1,central}$=20 ft/day; $K_{l1,west}$: 3.5 ft/day; K_{l2}: 3.5 ft/day; Recharge: between 0.5 and 20 in/yr	Mean error: -1.87 Mean absolute error: 2.77 RMS error: 3.30 Scaled RMS error: 13.27 % Significant improvement in calibration statistics. However, the flow direction in the WT area is still to the northeast rather than the northwest. There is still a systematic error evident in the calibration curve, whereby the modeled heads around many of the pumping wells are too high.
GE3	Added effluent channel river boundary	$K_{l1,east}$: 40 ft/day; $K_{l1,central}$=20 ft/day; $K_{l1,west}$: 3.5 ft/day; K_{l2}: 3.5 ft/day; Recharge: between 0.5 and 20 in/yr	Mean error: -1.73 Mean absolute error: 2.57 RMS error: 3.13 Scaled RMS error: 12.59 % Similar calibration statistics to GE3, however, the flow direction in the WT area now is to the northwest, as measured. There is still a systematic error evident in the calibration curve, whereby the modeled heads around many of the pumping wells are too high.
GE4	**Varied conductivity, particularly around the pumping wells.**	**$K_{l1,east}$: avg=40, min=15, max=100 ft/day;** **$K_{l1,central}$: 40 ft/day;** **$K_{l1,west}$: avg=3.5, min=3.0, max=3.5 ft/day;** **K_{l2}: avg=3.5 ft/day, min=3.5, max=30 ft/day;** **Recharge: between 0.5 and 20 in/year.**	**Mean error: 0.25** **Mean absolute error: 1.0** **RMS error: 1.4** **Scaled RMS error: 5.64 %** **Significantly improved the calibration statistics. Removed the systematic error in the calibration curve. This simulation is the calibrated flow model used for future transport simulations.**

Table F-3
Summary of Transport-Model Parameter Values

Parameter	Nitrate		Ammonium	Basis
	Degradation Scenario	No-Degradation Scenario		
Sorption Retardation Coefficient (R)	None	None	2 (K_d = 0.00706 ft^3/kg)	Nitrate is a non-sorbing anion; Ammonium sorption estimate is conservative based on reported literature values (Drever, 1988)
Longitudinal Dispersivity	3 feet	3 feet	3 feet	Scale of the plume; calibration; (transport is relatively insensitive to dispersivity in this low range)
Longitudinal Dispersivity	0.3 feet	0.3 feet	0.3 feet	
Biodegradation Rate (year $^{-1}$)	0.62 year $^{-1}$	None	No biodegradation	Model calibration to measured concentrations; assumption of a stable, non-migrating plume; well within ranges reported in literature (see Section F.5.1.1).
Biodegradation Half Life (year)	1.12 year	None		

Table F-4
Transport-Model Calibration Simulations

ID	Objective	Input Parameters	Results
Waste Treatment Area Nitrate Simulations			
N1	Initial calibration run. Flow model from GE4.	Dispersion: $\alpha_l = 10$ ft; $\alpha_t = 1$ ft; $\alpha_v = 0.0$ ft Degradation Rate: None Initial Concentrations: None Source Concentration: 1000 mg/L Transport Solution: Finite Difference	Not very sensitive to dispersion
N2	Evaluate the sensitivity to dispersion.	Dispersion: $\alpha_l = 5$ ft; $\alpha_t = 0.5$ ft; $\alpha_v = 0.0$ ft Degradation Rate: None Initial Concentrations: None Source Concentration: 1000 mg/L Transport Solution: Finite Difference	Not very sensitive to dispersion
N3	Evaluate the sensitivity to dispersion.	Dispersion: $\alpha_l = 1$ ft; $\alpha_t = 0.1$ ft; $\alpha_v = 0.0$ ft Degradation Rate: None Initial Concentrations: None Source Concentration: 1000 mg/L Transport Solution: Finite Difference	Not very sensitive to dispersion
N5	Same as N2 but using particle tracking solution	Dispersion: $\alpha_l = 5$ ft; $\alpha_t = 0.5$ ft; $\alpha_v = 0.0$ ft Degradation Rate: None Initial Concentrations: None Source Concentration: 1000 mg/L Transport Solution: MOC	Some minor numerical dispersion is apparent. Therefore will use the particle tracking solution technique method of characteristics (MOC) from now on.
N6	With 1st order degradation	Dispersion: $\alpha_l = 5$ ft; $\alpha_t = 0.5$ ft; $\alpha_v = 0.0$ ft Degradation Rate: 1.8 year^{-1} Initial Concentrations: None Source Concentration: 1000 mg/L Transport Solution: MOC	Simulated plume migrates less than the measured plume
N7	Increase biodegradation rate, increase source conc.	Dispersion: $\alpha_l = 5$ ft; $\alpha_t = 0.5$ ft; $\alpha_v = 0.0$ ft Degradation Rate: 0.62 year^{-1} Initial Concentrations: None Source Concentration: 1100 mg/L Transport Solution: MOC	Reasonably good match with the measured plume. Plume is stable within 9 years.
N8	Same as N7 but with no degradation, determine conservative impacts	Dispersion: $\alpha_l = 5$ ft; $\alpha_t = 0.5$ ft; $\alpha_v = 0.0$ ft Degradation Rate: None Initial Concentrations: None Source Concentration: 1100 mg/L Transport Solution: MOC	Plume extends much farther out than currently measured plume. Plume is stable after 10 years.
N10	Degradation model scenario; Same as N7, but with no source; Includes degradation	Dispersion: $\alpha_l = 5$ ft; $\alpha_t = 0.5$ ft; $\alpha_v = 0.0$ ft Degradation Rate: : 0.62 year^{-1} Initial Concentrations: stable plume from N7 Source Concentration: none Transport Solution: MOC	Refer to Section F.6
N11	No degradation model scenario; Same as N7, but with no source; Includes no degradation	Dispersion: $\alpha_l = 5$ ft; $\alpha_t = 0.5$ ft; $\alpha_v = 0.0$ ft Degradation Rate: None Initial Concentrations: stable plume from N7 Source Concentration: none Transport Solution: MOC	Refer to Section F.6
Waste Treatment Area Ammonia Simulations			
A1	Determine if model can reproduce a reasonable ammonia plume, including only sorption	Dispersion: $\alpha_l = 5$ ft; $\alpha_t = 0.5$ ft; $\alpha_v = 0.0$ ft Sorption: $K_d = 0.00706$ ft^3/kg; $R_{sand}=2.0$ Degradation Rate: 0.365 year^{-1} Initial Concentrations: None Source Concentration: 200 mg/L Transport Solution: MOC	Reasonable calibration after 11 years

PLATE

Appendix G

Data Validation Memoranda

RESEARCH TRIANGLE INSTITUTE

RTI

Center for Environmental Measurements and Quality Assurance

Data Validation Memorandum

Privileged and Confidential

To: Jeff W. Reynolds, P.G.
Project Hydrogeologist

April 13, 1999

Through: Andrew D. Stahl, P.G.
Hydrogeologist

From: Cynthia A. Salmons, MSPH CAS
Chemist

Subject: Laboratory Data Validation
6448.019 Sampling February 1999

This data validation memorandum has been prepared for samples analyzed by Oxford Laboratories, Inc., (Oxford) for nitrate, fluoride, and ammonia, and by Research Triangle Institute for uranium (RTI sample nos. 101-166).

Validation and review of the referenced data packages were performed on the quality control (QC) data presented in the analytical reports, using Research Triangle Institute's (RTI's) *Data Validation Standard Operating Procedure* (SOP), which was prepared with the guidance of the *National Functional Guidelines for Inorganic Data Review* (US EPA, 1994). Table A-1 presents definitions of qualifier "flags" that have been applied to selected data. Table A-2 presents the data that have been qualified on the basis of the data validation described in this memorandum.

Sixty-six water samples (including 1 performance evaluation (PE) sample, 3 sets of field duplicate samples, and 3 field blanks) were analyzed. The laboratory data were reviewed to evaluate compliance with this method and the quality of the data reported. The results of the review are summarized in this memorandum.

1.0 Data Completeness

All analyses were performed as requested on the chain of custody.

3040 Cornwallis Road • Post Office Box 12194 • Research Triangle Park, North Carolina 27709-2194 USA
Telephone 919 541-8758 • Fax 919 541-8830

2.0 Preservation and Holding Time

The samples were preserved as required. All samples were analyzed within holding times, which are 180 days for uranium, 28 days for fluoride and ammonia, and 48 hours for nitrate.

3.0 Calibration

An inspection of the instrument calibrations was not required for this data validation.

4.0 Instrument Performance Check

An evaluation of the instrument performance check was not required for this data validation.

5.0 Blanks

5.1 Method Blanks

Six method blanks were analyzed for uranium, eight for ammonia, seven for fluoride, and nine for nitrate. There were no detects in these blank samples.

5.2 Field Blanks

There were no detects in the three sets of field blanks, except ammonia at a level of 0.21 in sample number 165. Based on this detection, positive ammonia values below 1.05 (5 x 0.21) are flagged Ub. These samples are listed in Table A-2.

6.0 Laboratory Control Samples

One laboratory control sample (LCS) was analyzed for uranium, 16 for ammonia, 15 for fluoride, and 11 for nitrate. All of these analyses were within the acceptance limits of 80%-120% recovery.

7.0 Laboratory Duplicates

Six sets of laboratory duplicate samples were analyzed for uranium, 11 for ammonia, 11 for fluoride, and nine for nitrate. All of the analyses met QC acceptance criteria (≤ 30% Relative Percent Difference [RPD]), except for ammonia in sample 106. The ammonia results for the laboratory duplicates for this sample were <0.20 and 0.29. As these data were previously flagged Ub (see Section 5.2), no further qualification is required.

8.0 Field Duplicates

Samples from CW-1A, WTP-20, and WT-1 were used for field duplicate analyses. The QC acceptance criteria (primary-duplicate sample RPD ≤ 50%) were met by all compounds in these sample sets.

9.0 Performance Evaluation Sample

High-Purity Standards lots 904804 and 904805 (sample 117) were used for PE analysis. The QC acceptance criteria specify that the measured concentrations agree with the certified values to within 80-120%. The PE results met all QC criteria (%R).

10.0 Laboratory Spikes

Five laboratory spikes were prepared for uranium, ten for ammonia, ten for fluoride, and ten for nitrate. All of these were within the 80-120% recovery acceptance limit.

11.0 Overall Data Quality Assessment

Overall, the data quality appears to be good. Minor qualifications were required based on the limited QC criteria that could be evaluated, as described in Section 5.2. Qualified data are listed in Table A-2. The qualifications summarized in this memorandum should be considered in evaluating and using the data.

Table A-1

Explanation of Data Validation Qualifiers

Data Flag	Data Qualifier Explanation
J	The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.
Jh	The approximate concentration is probably biased towards higher values than the actual concentration of the analyte in the sample.
Jl	The approximate concentration is probably biased towards lower values than the actual concentration of the analyte in the sample.
R	The sample results are rejected due to serious deficiencies in the ability to analyze the sample and meet quality control criteria. The presence or absence of the analyte cannot be verified.
U	The analyte was analyzed for, but was not detected above the reported sample quantitation limit.
Ub	The sample result is qualitatively suspect because the analyte was detected in a field and/or laboratory blank at a similar level.
UJ	The analyte was not detected above the reported sample quantitation limit. However, the reported quantitation limit is approximate and may or may not represent the actual limit of quantitation necessary to accurately and precisely measure the analyte in the sample.

Table A-2

Sample Results Qualified Based on Acceptance Criteria

Sample	Compound	Result	Qualifier*	Reason
101	Ammonia	0.22	Ub	Detection in field blank at 0.21
106	Ammonia	0.29	Ub	Detection in field blank at 0.21
109	Ammonia	0.22	Ub	Detection in field blank at 0.21
118	Ammonia	0.21	Ub	Detection in field blank at 0.21
119	Ammonia	0.27	Ub	Detection in field blank at 0.21
121	Ammonia	0.27	Ub	Detection in field blank at 0.21
125	Ammonia	0.21	Ub	Detection in field blank at 0.21
129	Ammonia	0.21	Ub	Detection in field blank at 0.21
133	Ammonia	0.21	Ub	Detection in field blank at 0.21
134	Ammonia	0.49	Ub	Detection in field blank at 0.21
143	Ammonia	0.97	Ub	Detection in field blank at 0.21
144	Ammonia	0.56	Ub	Detection in field blank at 0.21
150	Ammonia	0.28	Ub	Detection in field blank at 0.21
152	Ammonia	0.62	Ub	Detection in field blank at 0.21
156	Ammonia	0.90	Ub	Detection in field blank at 0.21
158	Ammonia	0.62	Ub	Detection in field blank at 0.21

* See Table A-1 for definition of qualifiers

RTI

RESEARCH TRIANGLE INSTITUTE

Center for Environmental Measurements and Quality Assurance

Data Validation Memorandum

Privileged and Confidential

To: Andrew D. Stahl, P.G.
Hydrogeologist

September 23, 1999

From: Andrea C. McWilliams Andrea C. McWilliams
Environmental Scientist

Subject: Laboratory Data Validation, RTI Project 6448-019
Monitoring for the WT CaF_2-Removal Operation
3rd Quarter Sampling, July 1999

This data validation memorandum has been prepared for samples collected on July 27-28, 1999, and analyzed by Oxford Laboratories, Inc., (Oxford), and by Research Triangle Institute's Center for Environmental Measurements and Quality Assurance Laboratory, (RTI CEMQA Laboratory) (RTI Chain-of-Custody [COC] Nos. 176-194). The samples were collected during the first routine monitoring event conducted in general accordance with the procedures described in the August 2, 1999, draft *Groundwater and Surface-Water Field Sampling Plan, Routine Monitoring for the Calcium-Fluoride Removal Operation (FSP).*

Validation and review of the referenced data packages were performed on the quality control (QC) data presented in Oxford's and RTI CEMQA Laboratory's analytical reports in accordance with the procedures set forth in RTI's *Standard Operating Procedure for the Validation of Inorganic Data* (SOP), which was prepared with the guidance of the *National Functional Guidelines for Inorganic Data Review* (US EPA, 1994).

Data were reviewed for the following:

Parameter/Method	Matrix	No. of Samples
Fluoride/SM 4500-F^--C	water	19
Uranium/ EPA Method 200.8	water	19

The laboratory data were reviewed to evaluate compliance with the applicable method and the quality of the data reported. The results of the review are summarized in this memorandum.

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Telephone 919 541-6644 • Fax 919 541-8830

1.0 Data Completeness

All analyses were performed as requested on the COC form.

2.0 Preservation and Holding Time

The samples were preserved as required. All samples were analyzed within holding times, which are 28 days for fluoride, and 180 days for uranium.

3.0 Calibration

An inspection of the instrument calibrations was not required for this data validation.

4.0 Instrument Performance Check

An evaluation of the instrument performance check was not required for this data validation.

5.0 Blanks

5.1 Method Blanks

Six laboratory blanks were analyzed with these samples. No target compounds were detected in these blanks.

5.2 Field Blanks

One field blank (FB) was included in these analyses. No target compounds were detected in this blank.

6.0 Internal Standard Performance

An evaluation of IS performance was not required for this data validation.

7.0 Laboratory Control Samples

Six laboratory control samples (LCS) were analyzed with these field samples. All of the results were within the QC acceptance criteria.

8.0 Matrix Spikes

Six matrix spike analyses were performed on these field samples. The results were within the QC acceptance criteria.

9.0 Laboratory Duplicates

Five laboratory duplicate analyses were performed with these analytical batches. The results were within the QC acceptance criteria.

10.0 Field Duplicates

One set of blind field duplicates was analyzed with these batches. The relative percent differences were within the QC acceptance criteria.

11.0 Performance Evaluation Sample

High Purity Standards (HPS) provided the standard solutions used as performance evaluation (PE) samples (COC ID No. 190). HPS Standard lot 920718 was submitted as a double-blind PE sample for fluoride analysis, and HPS Standard lot 920719 was submitted as a double-blind PE sample for uranium analysis. The PE analyses met the performance criteria of 80-120%R, with recoveries of 98 and 115%R for fluoride and uranium, respectively.

12.0 Overall Data Quality Assessment

No qualifications were required based on the QC criteria that were evaluated. All data should be considered complete, good quality, and useable for their intended purpose.

RESEARCH TRIANGLE INSTITUTE
RTI

Center for Environmental Measurements and Quality Assurance

Data Validation Memorandum

Privileged and Confidential

To: Andrew D. Stahl, P.G.
Hydrogeologist

September 23, 1999

From: Andrea C. McWilliams Andrea C. McWilliams
Environmental Scientist

Subject: Laboratory Data Validation, RTI Project 6448-020
Waste Treatment Area Principal-Aquifer Groundwater Monitoring
3rd Quarter Sampling, August 1999

This data validation memorandum has been prepared for samples collected on August 9-11, 1999, and analyzed by Oxford Laboratories, Inc., (Oxford), and by Research Triangle Institute's Center for Environmental Measurements and Quality Assurance Laboratory, (RTI CEMQA Laboratory) (RTI Chain-of-Custody [COC] Nos. 195-220). The samples were collected during the first routine sampling and analysis event designed to monitor principal-aquifer groundwater quality in the Waste Treatment area.

Validation and review of the referenced data packages were performed on the quality control (QC) data presented in Oxford's and RTI CEMQA Laboratory's analytical reports in accordance with the procedures set forth in RTI's *Standard Operating Procedure for the Validation of Inorganic Data* (SOP), which was prepared with the guidance of the *National Functional Guidelines for Inorganic Data Review* (US EPA, 1994).

Data were reviewed for the following:

Parameter/Method	Matrix	No. of Samples
Ammonia/SM 4500-NH_3	water	24
Nitrate/SM 4500-NO_3^--E	water	25
Uranium/ EPA Method 200.8	water	9

The laboratory data were reviewed to evaluate compliance with the applicable method and the quality of the data reported. The results of the review are summarized in this memorandum.

1.0 Data Completeness

All analyses were performed as requested on the COC form.

2.0 Preservation and Holding Time

The samples were preserved as required. All samples were analyzed within holding times, which are 28 days for ammonia, 48 hours for nitrate, and 180 days for uranium.

3.0 Calibration

An inspection of the instrument calibrations was not required for this data validation.

4.0 Instrument Performance Check

An evaluation of the instrument performance check was not required for this data validation.

5.0 Blanks

5.1 Method Blanks

Nine laboratory blanks were analyzed with these samples. No target compounds were detected in these blanks.

5.2 Field Blanks

One field blank (FB) was included in these analyses. No target compounds were detected in this blank.

6.0 Internal Standard Performance

An evaluation of IS performance was not required for this data validation.

7.0 Laboratory Control Samples

Ten laboratory control samples (LCS) were analyzed with these field samples. All of the results were within the QC acceptance criteria.

8.0 Matrix Spikes

Eight matrix spike analyses were performed on these field samples. All results were within the QC acceptance criteria.

9.0 Laboratory Duplicates

Eight laboratory duplicate analyses were performed with these analytical batches. The results were within the QC acceptance criteria.

10.0 Field Duplicates

One set of blind field duplicates was analyzed with these batches. The relative percent differences (RPD) were within the QC acceptance criteria.

11.0 Performance Evaluation Sample

High Purity Standards (HPS) provided the standard solutions used as performance evaluation (PE) samples (COC ID No. 215). HPS Standard lot 922104 was submitted as a double-blind PE sample for nitrate analysis. The PE analysis met the performance criteria of 80-120 percent recovery (%R), with a recovery of 104%R for nitrate.

12.0 Overall Data Quality Assessment

No qualifications were required based on the QC criteria that were evaluated. All data should be considered complete, good quality, and useable for their intended purpose.

RESEARCH TRIANGLE INSTITUTE

RTI

Center for Environmental Measurements and Quality Assurance

Data Validation Memorandum

Privileged and Confidential

To: Andrew D. Stahl, P.G.
Hydrogeologist

December 9, 1999

From: Andrea C. McWilliams Andrea C. McWilliams
Environmental Scientist

Subject: Laboratory Data Validation, RTI Project 6448-019
Monitoring for the WT CaF_2-Removal Operation
Fourth Quarter Sampling, October 1999

This data validation memorandum has been prepared for samples collected on October 25-28, 1999, and analyzed by Oxford Laboratories, Inc., (Oxford), and by Research Triangle Institute's Center for Environmental Measurements and Quality Assurance Laboratory (RTI CEMQA Laboratory). The samples were collected during the second routine monitoring event conducted in accordance with the procedures described in the September 21, 1999, *Groundwater and Surface-Water Field Sampling Plan, Routine Monitoring for the Calcium-Fluoride Removal Operation* (RTI Report No. 6448-019/002/01F). The information on the chain-of-custody (COC) forms completed for this sampling event is summarized as follows:

Parameter/Method	Matrix	No. of Samples
Fluoride/SM 4500-F^--C	water	19
Uranium/ EPA Method 200.8	water	19

Validation was performed on the quality control (QC) data and other information presented in the laboratories' analytical reports. The validation was conducted in accordance with the procedures set forth in RTI's *Standard Operating Procedure for the Validation of Inorganic Data* (SOP), which was prepared with the guidance of the *National Functional Guidelines for Inorganic Data Review* (US EPA, 1994). Evaluation of the initial and continuing calibrations is not required by the SOP.

1.0 Data Completeness

All analyses were performed as requested on the COC forms.

2.0 Preservation and Holding Time

The samples were preserved as required. All samples were analyzed within holding times, which are 28 days for fluoride, and 180 days for uranium.

3.0 Blanks

3.1 Method Blanks

Four method blanks were analyzed for fluoride, and three for uranium. No target compounds were detected in these blanks.

3.2 Field Blanks

One field blank (FB) was included for fluoride and uranium. No target compounds were detected in this blank.

4.0 Laboratory Control Samples

Four laboratory control samples (LCSs) were analyzed for fluoride, and three for uranium. All of the results were within the QC acceptance criteria.

5.0 Matrix Spikes

Four matrix spike analyses were performed for fluoride and uranium. The results were within the QC acceptance criteria.

6.0 Laboratory Duplicates

Three laboratory duplicate analyses were performed for fluoride and uranium. The results were within the QC acceptance criteria.

7.0 Field Duplicates

One set of blind field duplicates was analyzed with these batches. The relative percent difference was within the QC acceptance criteria.

8.0 Performance Evaluation Sample

High Purity Standards (HPS) provided the standard solutions used as performance evaluation (PE) samples (COC ID No. 241). HPS Standard lot 929910 was submitted as a double-blind PE sample for fluoride analysis, and HPS Standard lot 929911 was submitted as a double-blind PE sample for uranium analysis. The PE analyses met the performance criteria of 80-120% recovery, with recoveries of 104 and 96% for fluoride and uranium, respectively.

9.0 Overall Data Quality Assessment

No qualifications were required based on the QC criteria that were evaluated. All data should be considered complete, good quality, and useable for their intended purpose.

RESEARCH TRIANGLE INSTITUTE

RTI

Center for Environmental Measurements and Quality Assurance

Data Validation Memorandum

Privileged and Confidential

To: Andrew D. Stahl, P.G.
Hydrogeologist

December 10, 1999

From: Andrea C. McWilliams Andrea C. McWilliams
Environmental Scientist

Subject: Laboratory Data Validation, RTI Project 6448-020
Waste Treatment Area Principal-Aquifer Groundwater Monitoring
Fourth Quarter Sampling, October 1999

This data validation memorandum has been prepared for samples collected on October 25-28, 1999, and analyzed by Oxford Laboratories, Inc., (Oxford), and by Research Triangle Institute's Center for Environmental Measurements and Quality Assurance Laboratory (RTI CEMQA Laboratory). The samples were collected during the second routine sampling and analysis event designed to monitor principal-aquifer groundwater quality in the Waste Treatment area. The information on the chain-of-custody (COC) forms completed for this sampling event is summarized as follows:

Parameter/Method	Matrix	No. of Samples
Ammonia/SM 4500-NH_3-E	water	24
Nitrate/SM 4500-NO_3^--F	water	25
Uranium/ EPA Method 200.8	water	24

Validation was performed on the quality control (QC) data and other information presented in the laboratories' analytical reports. The validation was conducted in accordance with the procedures set forth in RTI's *Standard Operating Procedure for the Validation of Inorganic Data* (SOP), which was prepared with the guidance of the *National Functional Guidelines for Inorganic Data Review* (US EPA, 1994). Evaluation of the initial and continuing calibrations is not required by the SOP. The RTI CEMQA Laboratory re-analyzed three samples (COC ID No. 249 and 250 and its duplicate 251) for uranium because the initial analytical results did not conform to historical trend. Upon re-analysis, two of the three uranium concentrations were notably different from the initial results, and these re-analyses are consistent with historical trends. The laboratory identified that there was a problem with the initial sample preparations, and so only the second set of analyses is considered in this validation.

1.0 Data Completeness

All analyses were performed as requested on the COC forms.

2.0 Preservation and Holding Time

The samples were preserved as required. All samples were analyzed within holding times, which are 28 days for ammonia, 48 hours for nitrate, and 180 days for uranium.

3.0 Blanks

3.1 Method Blanks

Four method blanks were analyzed for ammonia, five for nitrate, and three for uranium. No target compounds were detected in these blanks.

3.2 Field Blanks

One field blank (FB) was included for ammonia, nitrate, and uranium analyses. No target compounds were detected in this blank.

4.0 Laboratory Control Samples

Four laboratory control samples (LCSs) were analyzed for ammonia, six for nitrate, and three for uranium. All of the results were within the QC acceptance limits of 80-120 percent recovery (%R).

5.0 Matrix Spikes

Four matrix spike (MS) analyses were performed on ammonia, five for nitrate, and three for uranium. All of the results were within the QC acceptance limits of 80-120%R.

6.0 Laboratory Duplicates

Four laboratory duplicates analyses were performed for ammonia, and two were performed for nitrate and uranium. The results were within the QC acceptance criteria (≤ 30 RPD).

7.0 Field Duplicates

A blind duplicate pair of samples was collected from monitoring well WT-14B for analysis of ammonia, nitrate, and uranium. The QC acceptance criteria were met.

8.0 Performance Evaluation Sample

High Purity Standards (HPS) provided the standard solution used as a performance evaluation (PE) sample (COC ID No. 240). HPS Standard lot 929912 was submitted as a double-blind PE sample for nitrate analysis. The PE analysis met the performance criteria of 80-120%R, with a recovery of 102% for nitrate.

9.0 Overall Data Quality Assessment

No qualifications were required based on the QC criteria that were evaluated. All data should be considered complete, good quality, and useable for their intended purpose.